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1 Abbreviations and acronyms

Partner Acronyms:

ASCAMM	Fundaciò Privada ASCAMM, Spain
REDINN	Rete Europea dell'Innovazione, Italy
ION	Institute of Nanotechnology, UK
MTV	Malsch TechnoValuation, Netherlands
ZSI	Zentrum für Soziale Innovation, Austria
VTT	Technical Research Centre of Finland, Finland
RELANS	Latin American Nanotechnology and Society Network, Brazil
MINCyT	The Ministry of Science, Technology and Productive Innovation, Argentina
CIMAV-CONACYT	Centro de Investigación en Materiales Avanzados, S.C, Mexico
MEC	Ministry of Education and Culture, Uruguay
EUROCHILE	Eurochile Business Foundation, Chile

Abbreviations and acronyms used in this report

CoI	Community of Interest
LA:	Latin America
NMP	Nanosciences, Nanotechnologies, Materials & New Production Technologies
NTD	Neglected Tropical Disease
OIP	Open Innovation Platform
STEM	Science, Technology, Engineering and Mathematics
COST	European Cooperation in Science and Technology
STI	Science and Technology Innovation
ETP	European Technology Platforms
EIP	European Innovation Partnerships

2 Summary

This roadmap shows a way forward for initiatives that stimulate research, development and innovation of nanotechnologies and nanomaterials in Latin America (LA). It was developed in the project on Nanosciences, Nanotechnologies, Materials and New Production Technologies Deployment in Latin American Countries (NMP-DeLA) funded by the European Union. The main objective of the NMP-DeLA project was to develop a series of activities between European and Latin American countries, to strengthen the local research and training potential as a way of facilitating the deployment of nano and advanced materials technologies in areas of major societal challenge in LA: energy, water and health.

A bibliometric study, literature review and stakeholder engagement during workshops, summer schools and interviews revealed wide disparities between countries and many weaknesses in the current higher education, research, development and innovation system in most countries in LA.

This roadmap focuses on the applications of nanotechnologies and nanomaterials for selected societal challenges that are relatively more important to LA: health, water and energy. The results of the roadmap exercise are discussed in the context of the wider status of NMP in LA, and specifically for each of the application areas.

Generic results concerning NMP:

It is important to realise that most of the **research** in LA concerning nanotechnologies, nanosciences, materials and new production technologies (NMP) is still at the level of basic research and that there is a lack of educated nanoscientists and nanoengineers and of research equipment, infrastructure and disposables (chemicals and materials for experiments). An important element of the roadmap is therefore to focus on capacity building for research in nanoscience and nanotechnology in LA, to create the conditions for nano-innovation in the long term. This can be achieved through:

- Consolidating and strengthening existing collaborations between Latin American and European partners within the wider NMP-DeLA Community of Interest.
- Bridging the gap between academia, industry and other stakeholders for capacity building.
- Improving networking to overcome fragmentation.

Policy makers from Europe and LA should strengthen the local capacities for innovation in nanoscience and nanotechnology by agreeing a common long term strategy and by pooling resources for common research and innovation priorities as part of the European Union and Community of Latin American and Caribbean States (EU-CELAC) policy dialogue. One of the key issues is a lack of reliable long term funding. The European Horizon 2020 programme offers a good starting point with its 7-year budget horizon. However, it is important that national funding within Latin America is also coordinated, as well as with European, North American and other funding sources including World Bank, International Monetary Fund (IMF), and preferably also venture capital. The participating Ministries in NMP-DeLA (from Argentina: the Ministry for Science, Technology and Productive Innovation and from Uruguay: Education and Culture, and Industry, Energy and Mining)

and the European Commission should take the initiative for such coordinated funding. As Brazilian and Mexican federal and state funding councils must fund their own researchers participating in projects in the EU H2020 programme, these should be engaged in coordinating funding strategies from the start. In the short term, the sector dialogues could offer funding for cooperative projects in cooperation between the EU and Brazil.[1]

A balanced funding strategy is needed including research, infrastructure, education, as well as environment, health and safety (EHS) and ethical, legal and social aspects (ELSA). The United Nations Institute for Training and Research (UNITAR) focuses on training and capacity building of governments in developing countries and has published a pilot "Guidance for Developing a National Nanotechnology Policy and Programme" (UNITAR, 2011). This could form the basis for such regional coordination in LA as well as EU-Latin American cooperation.

The current work of the Argentinean Ethics Board CECTE on a code of conduct for nanotechnology research could offer a starting point for introducing Latin American perspectives in the EU-Latin American dialogue on **Responsible Research and Innovation (RRI)**. On the European side, the materials and methodologies collected in the RRI-tools project can also foster the discussion on a common approach.[2]

Education, awareness raising and communication to policy makers and the general public are needed and should be implemented early enough to allow for change of status in the applications of nanotechnologies for societal challenges in LA. These can build upon existing initiatives including the South and Meso-American Research Centres for Fundamental Research[3], NanoAndes[4], NanoDYF[5], ReLANS[6] and RENANOSOMA[7].

Health applications

The bibliometric analysis revealed two fundamental aspects of health application research and development within LA.

First, although there are considerable differences in resources and capabilities between countries, there is a considerable amount of research on nanomedicine in LA. Development of new drugs and therapies, drug delivery and materials for different applications are the most advanced areas of research. Research groups in most countries have some degree of cooperation with international research networks, within and outside the region. Enhancing cooperation between the European Union and Latin American countries will require further discussion on priority areas for cooperation.

Second, it is not an easy task to identify what research in the area of nanomedicine could be of social relevance for the Latin American region. On the one hand, most of the research is very basic in nature, so the potential applications and benefits are very difficult to envisage. On the other hand, several Latin American

[1] http://sectordialogues.org/.
[2] http://www.rri-tools.eu/.
[3] http://www.ictp-saifr.org/ and http://mctp.mx/index.html
[4] www.nanoandes.org, http://www.nanoandes2015.com/
[5] www.nanodyf.org
[6] www.relans.org
[7] http://www.nanotecnologiadoavesso.org/

countries have crossed the “epidemiological transition” and present a very similar pattern of diseases and causes of deaths to more developed countries. Although research on tropical diseases is still important, more research seems to be directed to medical conditions that have a global nature.

A specific roadmap on nanomedicine focusing on applications regarding infectious diseases (tropical diseases and tuberculosis in particular) and cancer has been produced in NMP DeLA. Most of the research in nanotechnology for medical applications is still at the basic research phase or focuses on platform technologies rather than therapies or diagnostics for tropical diseases, including tuberculosis, or cancer. As a result, the focus of a common European – Latin American strategy for the deployment of nanotechnology for health for the benefit of the Latin American population should aim at capacity building and translational research targeting those focus areas. A key unresolved dilemma for all stakeholders is the discrepancy between translational nanomedicine research and products for which a business case can be argued, e.g. for cancer therapies or diagnostics and research that targets applications in poverty related tropical diseases including tuberculosis.

Policy makers from Europe and LA could strengthen the local capacities for innovation in nanomedicine by agreeing a common long term strategy and by pooling resources for common research and innovation priorities as part of the EU-CELAC policy dialogue. It is important that government departments for health participate in this common policy making, along with departments responsible for research and economic affairs and other interested stakeholders. These stakeholders include research, industry (nanomedicine, pharmaceuticals, medical devices), investors, healthcare professionals, patients associations and non-governmental organizations (NGOs).

Researchers and companies active in nanomedicine in LA could contribute to strengthening these local capacities to innovate, by pooling resources in a Latin American Nanomedicine association as the regional hub in the International Society for Nanomedicine. The Argentinean Nanomedicine Association has already established the relevant contacts. From the European side the European Technology Platform (ETP) Nanomedicine has opened up to Argentina and this could be expanded to other Latin American countries. Nanofutures is also open to researchers, companies and other stakeholders from LA. This opportunity and the advantages for Latin Americans should be widely communicated to stakeholders via electronic means and direct contacts and presentations in LA.[8]

Biomedical nanoethics and Responsible Research and Innovation are being pursued by several actors in Latin America as well as Europe, but the coordination could be improved. At an international level, the United Nations Educational, Scientific and Cultural Organization (UNESCO) Bioethics Network[9] could be invited to play a coordinating role in building capacity for governing nanobiomedical ethics issues related to nanomedicine. They already have a programme for strengthening such capacity in LA.[10] In EU-Latin American dialogues on ethical, legal and social aspects or responsible research and innovation of nanomedicine in partic-

[8] www.nanofutures.eu
[9] http://en.unesco.org/partnerships/partnering/bioethics
[10] http://www.redbioetica-edu.com.ar/

ular, the ELSA board of the ETP Nanomedicine could take the initiative to open up to Latin American experts and stakeholders in cooperation with other national initiatives.[11]

Water applications

The bibliometric study revealed that water applications are considerably less investigated than health or energy applications in LA and in Euro-Latin American cooperation. However, co-authored publications and collaboration exist that involve Latin American and European partners in research and education and training. Furthermore, several large European headquartered engineering companies are already active in the water sector in LA, and several large and small companies are interested in nanotechnology for water applications, mostly in Brazil. That being said, nanotechnology is not a priority in international funding for water solutions, nor is water a priority in research funding for nanotechnology. Some projects have been funded on water applications in nanotechnology programmes, mostly in Europe.

To address this, **researchers** should set up international networks and conferences specifically targeting nanotechnology for water applications. This could be related to the nanotechnology working group of the International Water Association (IWA) or the OECD Working Party on Nanotechnology, that published a report on nanotechnology for water in 2011.

Regional and local **policy makers** should articulate demand for nano-enabled water technologies, which could be supported by the City Blueprint tool[12]. National policy makers should review environmental laws governing the water sector and where necessary introduce a billing system for potable water. This should help create a business case for innovative water purification systems in Latin America.

Industry and researchers should cooperate in scaling up nano-enabled water technologies from lab to pilot or full scale.

Responsible Research and Innovation in nanotechnology for water could be stimulated by targeting the following societal needs of large groups in the Latin American populations:

- Arsenic and Fluoride removal from ground water
- Remediation of effluents from mineral mining activities in several countries
- Desalination of sea water in (remote) coastal regions through point of use / small scale units

Energy applications

The bibliometric study revealed that there is considerable activity in research on nanotechnology for energy applications in 13 Latin American countries. Many Latin American researchers have co-authored publications with European partners in the period 2003-2012. Most research targets solar PhotoVoltaics (PV), followed by fossil fuels, energy storage and energy transport. Since 2004, Brazil has targeted nanotechnology for energy research in its national funding strategy, focusing on fuel cells, storage and PV.

Some companies are already active in nanotechnology for energy applications in Brazil, Mexico and Chile, often in cooperation with academia. Applications include solar PV for large-scale energy production but also

[11] www.etp-nanomedicine.eu

[12] http://www.watershare.eu/tool/city-blueprint/start/

for powering mobile devices. In 2014, Brazil announced plans for investing in solar PV for energy production, including 10 GW in the coming five years. This will open opportunities for European research organizations and industry in cooperation with Brazilian partners. The European Commission recently published a strategic energy technology roadmap. The message is not to optimize individual technologies, but look at the interactions.

At international level, **policy makers** could include nanotechnology as a key enabling technology in funding and investments in sustainable energy solutions. The energy mix of Latin American countries varies considerably making it difficult to design a common strategy to nanotechnology for energy applications. In terms of increasing bioenergy and energy for local use like in remote areas in agribusiness, there is a need for self-sustaining local energy supplies. There are opportunities for joint ventures between foreign companies and for instance Brazilian companies. One way to stimulate local development is to establish projects with local fabrication facilities or local research council funding.

Public and private partners should cooperate in an integral EU-Latin American R&D&I programme for technologies with readiness levels 1 to 9, where nanotechnologies for solar PV should gradually move from academia via public research centres to industrial partners. The industrial partners should be existing solar energy companies active in LA. In Europe, the EU PV clusters and PV platform offer good starting points.[13] It is important to look for niches such as lifecycle and stability testing of materials developed by others or those that specialize in a particular application for LA.

Niche markets for nanotechnology for energy include batteries, solar and energy harvesting modules for mobile devices, and stand-alone solar energy for agricultural uses in remote regions.

EU-Latin American cooperation should be embedded in broader **global networking** including North-South as well as South-South cooperation. As a spin-off from the NMP-DeLA project, the conference on Bridging Africa, LA and Europe on Water and Renewable Energies Applications (BALEWARE 2016) to be held in Africa will facilitate the start of such a global initiative.

Nanosafety

In LA, academic groups in several countries are already engaged in research on EHS aspects of nanomaterials, much of which is of good quality. However, there is a lack of coordination. In the short to medium term there are opportunities for international cooperation in the World Health Organization (WHO) Healthy Workplace Programme, that will support policy making and international networking.[14] Brazil has already joined the European NanoREG project[15] and the European Nanosafety Cluster[16] is also open to Latin American participants. It may be worthwhile to explore opportunities for other Latin American countries to follow suit. In addition, synergies between NanoREG and RRI-tools could be explored.

Indicators

[13] http://www.eupvclusters.eu/ and http://www.eupvplatform.org/.
[14] http://www.who.int/occupational_health/healthy_workplaces/en/
[15] www.nanoreg.eu

In order to enable monitoring the impacts of the proposed activities on societal challenges in the areas of health, energy and water, a number of indicators have been developed in the framework of the NMP-DeLA project. Short-term outcome indicators as well as long term impact indicators are included. The outcomes are directly attributable to the intervention, while impacts may directly or indirectly and intentionally or unintentionally be caused by more than one outcome. Worldwide, there is increasing interest in the development of nanotechnology specific indicators. The OECD plays an international coordinating role in this development. From another perspective, the EU is stimulating the development of indicators for responsible research and innovation. A milestone in this endeavour is a report by an expert group on "Policy Indicators for Responsible Research and Innovation" that was recently published by the European Commission.

The NMP-DeLA indicators have been developed on the basis of recommendations from expert interviews and focus groups. These indicators have not been tested yet. We recommend to do this in follow-up projects. The indicators are clustered by field of intervention (the complete list is available in chapter 9):

- Research
- Nanosafety and risk management
- Skill development
- Policy making and funding
- Application and industry
- Ethical, Legal and Societal Aspects, Responsible Research and Innovation and Public Engagement

Concluding remarks

The main recommended steps to implement the roadmap are included in chapter 10. Policy makers and researchers and industrialists are suggested to take a number of actions in the short, medium and long term.

[16] www.nanosafetycluster.eu

3 Introduction

This roadmap shows a way forward for higher education, research, development and innovation in nano-technologies and nanomaterials in Latin America (LA). It was developed in the project on Nanosciences, Nanotechnologies, Materials and New Production Technologies Deployment in Latin American Countries (NMP-DeLA) funded by the European Union. The main objective of the NMP-DeLA project is to develop a series of activities between European and Latin American countries, that strengthen the local research and training potential as a way of facilitating the deployment of nano and advanced materials technologies in areas of major societal challenge in Latin America: energy, water and health. The objective of this report (Project Deliverable 2.3) is to produce a qualitative roadmap and recommendations for action to be disseminated among the Community of Interest and published online for future use. The Community of Interest consists of researchers, industrialists, policy makers and other stakeholders who have self-registered via the NMP-DeLA website www.nmp-dela.eu.

The roadmap is targeted to all stakeholders, especially those from policymaking, academia and industry. Members of these stakeholder groups have been consulted during the elaboration of the roadmap via their participation in specific workshops, individual and focus group interviews. More general information on the state of the art and future strategies has been developed through a literature review carried out by VTT (Ongoing Roadmaps on Nanotechnologies for Health, Water and Energy). Furthermore, in the framework of the NMP DeLA project a bibliometric study was realized by ZSI and RELANS on nanomedicine research activities in LA. The main results are incorporated in this roadmap (the full report can be downloaded from the NMP-DeLA website[17]). Two approaches were used in the NMP DeLA project to identify nanotechnology R&D activities in LA: a quantitative publication analysis based on bibliometric studies using the two major international citation databases available (Web of Science and Elsevier's Scopus) and a qualitative approach oriented to identify the main research groups, researchers and funding devoted to nanotechnology in six countries: Brazil, Mexico, Argentina, Chile, Colombia and Uruguay.

The aim of the roadmap is to guide stakeholders in the promotion of research and innovations that will have social and economic impacts on the developing countries in Latin America. Each section of the roadmap is prefaced with the question that was put to stakeholders participating in workshops or who were interviewed as part of the NMP-DeLA project. The first section of each chapter gives an overview of the state of the art, the second summarises recommendations by the stakeholders and the third discusses potential future developments mainly based on existing roadmaps mentioned by the stakeholders or found through literature and internet searches. The main reason for including the details is to improve transparency of how we reach the conclusions and recommendations presented in the summary.

Chapter 4 describes relevant generic aspects of NMP in LA. Good practices and recommendations are presented for stimulating the development of nanotechnology in LA in general, as proposed by the engaged Community of Interest members. This is followed by a discussion on how Latin American developments may

[17] http://www.nmp-dela.eu/index.php/reports

be embedded in current roadmaps for nanotechnology by international, European and national initiatives on both sides of the Atlantic.

Chapter 5 describes health applications in terms of generic trends and initiatives fostering nanotechnology for health (so-called platform technologies), and specific trends targeting infectious tropical diseases, such as tuberculosis, and cancer. Each section starts with relevant information about the state of the art of research, funding, industrial activities, policy making, responsible research and innovation, and international coordination. This is followed by proposals for good practices and recommendations by NMP-DeLA Community of Interest members about the same aspects. Finally, opportunities for producing technologies and applications in the future are outlined.

Chapter 6 describes solutions for water purification and desalination, followed by best practices and recommendations and concluding with strategies for producing future technologies and solutions. The chapter is illustrated by a case study on nanotechnology based solutions for conflicts over water pollution through mining.

Chapter 7 on energy applications includes information on the state of the art, recommendations and future strategies relevant for fostering applications of nanotechnology for energy solutions in Latin American countries. This considers photovoltaic and other renewable energy sources, as well as energy storage.

Chapter 8 describes current research and priorities for environment, health and safety aspects of nanotechnology research, including international programmes and initiatives, as well as governance issues and responsible research and innovation.

Chapter 9 provides an overview of the indicators that can be used to measure the impact of the recommendations in this roadmap.

Finally, Chapter 10 provides some conclusions on priority policy areas.

The information presented in this document originates from a wide variety of different sources. The overall data on research activities and centres as well as the relevant policies per country is based on the bibliometric study and an assessment of the state-of-the art carried out in the project (Invernizzi et al, 2015). The more technical developments from literature are taken over from the specific roadmaps for health, water and energy and referenced in those reports. Additional information about research activities and policy developments per country as well as recommendations and future visions are based on interviews and presentations and discussions during workshops and summer schools organised in the NMP-DeLA project. The identities of the sources are not always revealed in order to protect the privacy of the contributors. However, the complete list of respondents and participants is included in annex 3 to this roadmap. Additional literature including published roadmaps of relevant stakeholders are listed in the references to this roadmap and links to relevant websites with more information are included in footnotes. The lists of research institutes in LA and information on their activities are included in the bibliometric study (Invernizzi et al, 2015) and are not repeated here.

It should be noted that research and strategy development on nanotechnology, materials and production technologies and on science, technology and innovation in general in Latin America is organised by country or sometimes even by research group. Therefore many of the contributions by Community of Interest members focus on the local or national level rather than the level of the Latin American region in general.

4 NMP DeLA Roadmap for Deployment of Nanoscience, Nanotechnology, New Materials and Production Technologies in Latin America – General Aspects

4.1 State of the Art

This section responds to the question: What is already there for generic developments related to nanoscience, nanotechnology, new materials and production technologies in Europe and LA with a view to fostering international cooperation? This includes solutions identified for improving the general capacity to develop innovative applications of these technologies in LA.

4.1.1 Basic Research

Most research and development (R&D) in nanotechnology in the region has been done in public science and technology institutions. Brazil leads nanotechnology R&D in the three areas of interest (health, water and energy), followed by Mexico, and Argentina. Some institutions were more visible than others and had activities in all three areas. For instance, the Universidade de São Paulo (USP) and the Universidade Estadual de Campinas (UNICAMP), from Brazil, and the Universidad Nacional Autónoma de México, were always in the top five. The United States (US) is the main international collaborator. France and Spain are the main EU Member States that collaborate with LA countries. Within LA, Argentina and Brazil have the largest number of collaborations, regardless of the topic (Invernizzi et al, 2015).

Several networks have been established to foster international cooperation among nanoscientists from different disciplines in LA and with European partners. However, according to one survey respondent: "*if thanks to networks like NanoAndes, investigators of different countries know each other and have developed some collaboration, inside a country it is by no means the rule and national groups continue to be largely subcritical. It is probably due to various different factors such as:*

- *lack of money,*
- *professors (with PhDs) don't necessarily investigate; they teach in various universities,*
- *laboratories are poorly equipped (Peru, Venezuela, Ecuador) (and some in Argentina and Mexico),*
- *if they have equipment, there is no maintenance (or preventive maintenance) (Mexico, Venezuela) and equipment is often shutdown.*"

According to interviewed experts and stakeholders, the following capacities in basic nano-research exist in or are available to Latin American researchers, per country:

- The National Nanotechnology Laboratory (LANOTEC) in Costa Rica has invested US$10 million in equipment for characterization, synthesis and deployment of nanotechnologies for energy and water applications. They cooperate with the University of Alicante, Spain and Minatec in Grenoble, France.
- The Chilean Centre for Nanoscience and Nanotechnology (CEDENNA) started in 2009 with funding of 4000 million pesos under the national programme for investment in new technologies. It is hosted by University of Santiago de Chile and involves the most important universities from all over the country. The programme has resulted in over 500 articles in peer reviewed journals and 25 patents (4 more are under review). Applications are in health (2), animal health (4), food packaging (2), environment (3), remediation of water and soil, and electronics (3). The programme started with basic research groups.
- The Centre Biomaterials and Nano, at Universidad del Bío-Bío, Chile is working on nanocellulose, to exploit the properties of fibres in creating a material that is antibacterial and forms a barrier to water vapour. Other applications are in reinforcing matrixes, where it improves the mechanical, thermal and acoustic properties. There are also potential medical applications. However, commercial activity is taking place in North America, Europe and Asia, not yet in LA.
- Latin American researchers can make use of synchrotrons abroad through international cooperation. For example, Stanford in the USA offers free beam time, with CONACYT funding travel and subsistence for Mexican scientists. The International Centre for Theoretical Physics (ICTP) supports LA researchers financially to access Elettra in Trieste and Brazil also supports Latin American scientists financially.
- There is existing cooperation with Spanish and Portuguese research centres in nanotechnology and microsystems technology through an initiative of the Ibero-American Programme for the Development of Science and Technology (CYTED). Areas of cooperation include sensors (for example, see past IBERSENSORS biennial conferences).
- European and Latin American partners are also cooperating in FP7 and H2020 projects, the EU-Brazil concertation meeting in Campinas in 2014 and the EU-Argentinean sponsored NANOPYMES programme.
- In Brazil, 78% of the nanotechnology research groups are located in the South, South-East and North-East of the country. In 2011, the Ministry for Science, Technology and Innovation (MCTI) launched a call for nanotoxicology projects. Six networks were funded.
- In Brazil, SiS-Nano associated labs must open up 50% of their machine time to external public and private users. Strategic labs belong to the government, including the Centro de Tecnologias Estratégicas do Nordeste (CETENE) in the North East, the Instituto Nacional de Metrologia, Qualidade e Tecnologia (INMETRO)'s materials and mechanical metrology divisions and the Nanotechnology National Laboratory (LNNano) at UNICAMP.
- The following Brazilian labs are involved in the cooperation with NanoREG:
    - Instituto Nacional de Metrologia, Qualidade e Tecnologia INMETRO –scientific coordinator in Brazil;

- Centro de Tecnologias Estratégicas do Nordeste (CETENE), Laboratório Multiusuario de Nanotecnologia;
- Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA);
- Universidade Federal do Rio Grande do Sul (UFRGS);
- Universidade de São Paulo (USP)
- Universidade Federal do Rio Grande (FURG), Instituto de Ciências Biológicas (ICB)
- Universidade Federal de Minas Gerais (UFMG), Instituto de Ciências Biológicas (ICB);
- Universidade Estadual de Campinas (UNICAMP), Departmento de Química Inorgânica NanoBioss/Instituto de Química[18].

4.1.2 Education and Training

At a regional level, the existing NanoAndes[19] network can form the starting point for a common curriculum for nano-education, as this is already coordinating relevant activities from professors in a number of Latin American countries. There is considerable interest in collaboration in developing university and post-academic education in nanosciences and nanotechnologies in LA. Some universities already offer pre- and postgraduate education in nanotechnology, nanomaterials, and nano-engineering.

For example, one special course at UNAL in Colombia attracted 1300 students from all faculties in 2011, demonstrating interest in the topic beyond STEM students. At CIMAV/Monterrey, Mexico, Materials World Modules are used for education in nanotechnology, especially on structure-property relations.

4.1.3 Funding for Science, Technology and Innovation

The current funding landscape for international cooperation in nanoscience and nanotechnology involving partners from Europe and LA is rather fragmented. Schemes that are already funding nanoscience and nanotechnology projects and individual grants at an international level include the EU Horizon 2020 programme and the EU COST system that provides funding for exchange visits. CYTED funds networks involving Spain, Portugal and LA, and the Inter-American Development Bank (IDB) invests in government projects.

The Latin American non-profit fund RedCLARA[20] aims to stimulate academic networking in several fields selected after an evaluation in 2014. These include nanotechnology in three topical areas:

1) Structural materials and fibres improved by nanotechnology,
2) Nanoscale materials for chemical, environmental and energy systems,

[18] Source: http://www.nmp-dela.eu/images/brazil-2015/AnnaTempesta.pdf See also: www.nanoreg.eu
[19] www.nanoandes.org
[20] RedCLARA -Cooperación Latino Americana de Redes Avanzadas (Latin American Cooperation of Advanced Networks)- is a non-profit International Law Organization established on 23 December 2003 in Uruguay. It develops and operates the only Latin-American advanced Internet network. www.redclara.net

3) Optical, electronic, chemical, environmental, magnetic and biological sensors, as well as measurement and control systems based on nanotechnology.

National funding

In **Brazil**, there were four research networks in nanotechnology in 2001. The same year, the MCTI funded 4 Millennium Institutes (out of 17) in nanotechnology. These were also networks of institutes located at different institutions in the country. In 2003, a 4 year programme was set up in nanotechnology, launched in 2004. This had 5 main actions including: R&D projects with industry, networking, capacity building for labs, academic research projects in microsystems and nanotechnology. In 2005, 10 nanotechnology networks were funded, and in 2006/7 34 industrial projects. Between 2001-2010, the focus was on nanoscience and capacity building. Since 2011, the focus has been on nanotechnology, through funding National Institutes for S&T in nanotechnologies and an initiative to support specific labs allowing companies and external users to use the infrastructure: a National System of Nanotechnology Labs (SiS-Nano). In 2015-16 there are no new initiatives, mainly due to budget restraints. However, there are opportunities in the cooperation agreement of NanoREG and Brazil, signed in May 2015. Funding for nanotechnology comes from CNPq, CAPES, the Funding Authority for Studies and Projects (FINEP), the National Bank for Development (BNDES) and state-based Foundations for Science and Technology Support (FAPs). There are 8 priorities and a long list of instruments available for implementing the priorities. An example is the Science without Borders (SwB) programme supporting international mobility. Currently, the Brazilian Technology System (SIBRATEC) programme launched in 2014 supports a network of technological services to support nanotechnology in two lines: nanodevices and sensors, and nanomaterials and composites. Six mapping studies were published on the MCTI homepage by May 2015. [21]

The following international cooperation programmes involving Brazil are relevant to nanotechnology in general:

- Canada: 2+2 (cooperation between a lab and a company from Brazil and a lab and a company from Canada)
- Argentina-Brazil-China Centre for Nanotechnology
- China-Brazil Centre for Nanotechnology (2012) - Campinas hosts the national cooperation
- The India-Brazil-South Africa Dialogue Forum (IBSA)
- Current cooperation with Mexico and with Cuba
- Agribusiness: China, Canada and IBSA
- Environment and health: China, Canada and the EU (NanoREG)

The MCTI budget for international cooperation is already reserved for 2015/16.[22]

[21] C.f. presentation Alfredo de Souza Mendes, MCTI, Brazil, at NMP-DeLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu and http://mct.gov.br/index.php/content/view/77677.html

In **Mexico**, CONACYT funds research in all areas including nanosciences and nanotechnologies.[23]

In **Argentina**, the Agencia Nacional de Promoción Científica y Tecnológica (ANPCYT), the National Scientific and Technical Research Council (CONICET), the Argentinean Foundation for Nanotechnology (FAN), MINCYT and Banco Santander Rio, fund nanoscience and nanotechnology projects.

In **Chile**, the Production Development Corporation (CORFO) offers support to industrial innovation, entrepreneurship and investment through different instruments. It is strengthening technological capacities through international cooperation in R&D in nanotechnology after an international call for proposals that has been won by LEITAT Technological Centre, Spain, and CEDENNA.

In **Uruguay**,nanotechnology has been funded by different funding councils. Under the responsibility of the Ministry of Education and Culture (MEC): PENTI, DICYT and CIP. Under the responsibility of the Ministry of Industry, Energy and Mining (MIEM): Fondos Industriales Consejo sectorial. Under the responsibility of the University UDELAR: CSIC. The ANII has also funded nanotechnology projects.

In **Colombia**, the Administrative Department of Science, Technology and Innovation (COLCIENCIAS) and a fund for oil industry research fund international cooperation in nanotechnology,

According to a survey respondent, until recently financial tools from **Peru** were not sufficiently developed to be able to install applied laboratories (5-10M€) and use these in subsequent collaborations. Recently, the situation changed in Peru as the new activities of the Consejo Nacional de Ciencia, Tecnología y Innovacion Tecnológica (CONCYTEC) allow for the creation of new centres of excellence, return of national PhDs having left the country, etc.

Several **European** governments also support nanotechnology cooperation and mobility, including:

- Agence Nationale de Recherche (ANR) and the French Agricultural Research Centre for International Development (CIRAD), France,
- von Humboldt Foundation and the German Research Foundation (DFG), Germany,
- the Spanish government,
- The UK Government (Newton funding).

See for more information about recent investments in nanotechnology in Latin America Invernizzi et al. (2015).

[22] C.f. presentation Anna Tempesta, MCTI, Brazil, at NMP-DeLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu
[23] http://www.conacyt.mx/

4.1.4 Science, Technology and Innovation Policy Making

Nanotechnology is mentioned in the national science, technology and innovation strategies of twelve Latin American countries: Brazil and Mexico (since 2001), Argentina (since 2003), Colombia and Costa Rica (since 2004), Guatemala and Ecuador (since 2005), El Salvador and Peru (since 2006), Dominican Republic (since 2008), Uruguay (since 2009) and Panama (since 2010) (Foladori et al, 2012). However, the implementation of these strategies is rather diverse. Brazil has its national nanotechnology initiative and CONICET has a strategy to make Argentina more innovative (PICT) by 2020. In other countries, bottom up scientific networks or research projects focus on nanotechnology. More details are included in the NMP-DeLA Mapping study (Invernizzi et al, 2015).

National policies

In **Brazil**, MCTI has been supporting nanotechnology since 2001. By 2005, other Ministries also started activities in nanotechnology: the Ministry of Education in nanobiotechnology, the Ministry of Industrial Development and Foreign Trade organised a forum on nanoinnovations with companies in 2009, the Ministry of Health invested in the potential of nanotechnology for pharmaceuticals. Regulation also became an issue. Currently, the Brazilian national strategy for S&T is part of the “Brasil Maior” Plan. This includes 6 strategic sectors: aerospace, agribusiness, defence, energy, environment, health. The Brazil Nanotechnology Initiative (BNI) identified key nanotechnologies for these sectors. Sensors and nanomaterials are the main driving force. These nanotechnologies focus on the short to medium term. Currently, nanotechnology policy is coordinated by the National Secretariat for Innovation (SETEC). An inter-ministerial nanotechnology committee has been established and consists of representatives from 10 Ministries, including the Ministry of External Relations and the Ministry of Labour and Employment.[24]

In **Mexico**, the innovation policy of the state of Nuevo Leon focuses on cooperation in the triple helix (science, industry and government). The total output of Nuevo Leon accounts for one sixth of the GDP of the country. The policy aims to shift from a production to a creative economy and to foster economic integration with the USA.

In **Chile**, three national programmes have started in the national interest: sustainability and productivity in construction, intelligent industries and solar industry.

In Uruguay, nanotechnology is included as emerging transversal sector in the National Strategic Plan in Science, Technology and Innovation PENCTI. An inventory has been made of the state of the art of research, industrial activities and policy making in the country (Mendoza Muniz et al. 2013).

According to an interviewed expert, in **Costa Rica**, the national nanotechnology strategy focuses mainly on applications in energy and health, with some relevance to water.

The **French** government's policy for nanotechnology focuses on industrialization in cooperation with the French territories and Latin American countries including Brazil and Cuba, and the Southern Common Market (MERCOSUR) region.

4.1.5 Industry and Investment

In R&D and innovation in nanotechnology, private enterprises play a marginal role, with some presence mainly in Brazil (Invernizzi et al, 2015). The Argentinean Foundation for Nanotechnology (FAN)[25] is investing in companies and start-ups developing products based on nanotechnology. Companies working in nanotechnology for health, water and energy applications are included in the respective modules of the present roadmap.
A survey respondent, with years of experience in EU-Latin American cooperation in nanotechnology has encountered "*difficulties in associating companies with universities".* According to this respondent, in many countries substantial barriers still exist due to political reasons even if the economic situation seems to be better today than 15 years ago (except in Venezuela). Industrial careers continue to be rejected by students and there are few chances for students to be involved in national industries. He is of the opinion that "*an entrepreneurial spirit in education is probably growing and many small and medium enterprises (SMEs) begin to attract young researchers; but it is still difficult to connect these SMEs to laboratories in the university."*
Another participant remarked that cooperation with industry is difficult in Brazil because of bureaucracy, although government funding is available, and this is sometimes used by professors to set up spin-off companies.

National situations

According to Alfredo de Souza Mendes, in **Brazil**, in 2014, 331 companies were investing in nanotechnology in their own R&D, including some on energy and water. This has increased rapidly since 2005/6 when there were few companies active.[26] The government is stimulating industrial involvement in nanotechnology through the Platform iTEC which was established in March 2015. Companies can publish problems and Brazilian researchers offer solutions. This is a form of matchmaking that is receiving a lot of industrial interest.[27]

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[24] C.f. presentation Alfredo de Souza Mendes, MCTI, Brazil, at NMP-DeLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu and http://sectordialogues.org
[25] http://www.fan.org.ar/
[26] C.f. presentation Alfredo de Souza Mendes, MCTI, Brazil, at NMP-DeLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu

In **Chile**, CEDENNA is working on a number of projects developing innovative nanotechnology solutions for the food production sector, e.g. in food packaging, nanoparticles are incorporated that absorb ethylene from the fruit, and in a film for encapsulating nanoparticles in smart food packaging, antimicrobial material is released if food starts to rot.

Chilean companies have developed several nano-enabled products that are not directly relevant to applications for health, water and energy. Some examples are:

- Adrox in Chile has developed the AlwaysClean coatings for windows, reducing water use for cleaning by 80%, and a coating for car shields that requires 40% less washing. They sell the product directly to clients and only use certified nanoparticles. Their product has US Environmental Protection Agency (EPA) certification and others.
- In many countries there is interest in applying silver nanoparticles for antimicrobial purposes, while in Chile, copper is mined and used instead as antimicrobial coatings on textile and packaging, products, etc.

In **Mexico** C Bond Systems (a spin off from Rice University in the USA) is cooperating with the Technological Institute of Monterrey to set up a subsidiary or joint venture. C Bond Systems manufacture a reinforcing agent for polymers and glass based on carbon nanotubes. Applications include bomb proof glass and airplane shells that can absorb or deflect lightning strikes.

4.1.6 Ethical, Legal and Societal Aspects

The Latin American network for Nanotechnology and Society (ReLANS) coordinates social and human scientists studying ethical and societal aspects of nanotechnology all over LA.[28] In addition to this established network, several projects funded by CYTED, the EU and others stimulate research, networking and communication about ethical, legal and societal aspects of nanotechnology. These include the recently finished network NANODYF[29] and an earlier nanotechnology network funded by RedCLARA.

Currently, the Ibero-American Network for Nanotechnology (RIN)[30] that started in 2014 has members from nineteen Ibero-American and two other countries. It aims to disseminate information about nanotechnology to the general public.

National activities

At national level, the **Argentinean** Committee of Ethics in Science and Technology (CECTE) issued guidelines for responsible science in 2013.[31] This includes seven main principles as well as guidance for individual

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[27] http://plataformaitec.com.br/index.php
[28] www.relans.org
[29] http://www.nanodyf.org/
[30] http://www.rednano.org/
[31] http://www.cecte.gov.ar/pdf/000065-es.pdf

researchers and research organizations. The seven main principles are: respect for human rights, consolidation of democratic values and practices, contribution to peace and justice with special attention to the most vulnerable sectors, care for the environment, biodiversity and the biosphere as a whole, open access to knowledge and information, equal access to the benefits of knowledge, freedom of research and the development of the capacity for critical analysis and innovating creativity.

In **Mexico**, there is an ongoing study to revise existing regulations and incentives for creating new technologies, such as accredited public centres (marcos propicios) for technology transfer that targets societal problems. This considers what nanotechnology is being developed in different regions and how this might be disseminated to the market and wider society. [32]

In **Chile**, all FONDECYT grants require an evaluation of societal opportunities. Most consortia engage in raising public awareness (TV, newspapers, school), this stimulates multidisciplinary research involving natural and social scientists.

4.2 Good practices and Recommendations

What are good practices and recommendations for generic developments related to nanoscience, nanotechnology, new materials and production technologies in Europe and LA with a view to fostering international cooperation? This includes national & regional examples of actions for up-scaling innovation in these fields in general.

4.2.1 Basic Research

Several NMP-DeLA community members made general recommendations on research strategies, networking and exchange of experts and improvement of the circumstances and capacities for innovation in LA:

- A nanotechnology network should be established in LA, to start connecting people with complementary capabilities and the same objectives.
- Measures should be taken to identify local capacities for nanotechnology as well as problems that can be addressed by interdisciplinary and inter-institutional efforts.
- Institutions and initiatives like NMP-DeLA should help to identify linkages between research groups that might be able to help each other.
- Many Latin American research groups need to collaborate with experienced partners and invest in equipment and infrastructure.

[32] Information from a participant of the workshop in Monterrey, Mexico

- There is interest in researcher and student mobility, funding short visits to other universities and institutes.

Another suggestion mentioned by several interviewed experts is to use the biological and mineral resources found in LA as the basis for developing nanomaterials and nanotechnology enabled products. The eventual raw materials and production processes used in manufacturing nano-based products should be low cost.

European Clusters, such as the Engineering and Upscaling Cluster and the European Cluster for Catalysis as well as European Technology Platforms (ETP) could cooperate with Latin American partners to develop nanotechnology for health, water and energy applications. The common interests of Latin American Technological Platforms in NMP and cross-linking of technology providers platforms with sectoral applications platforms should be promoted, according to survey respondents. National platforms in European and Latin American countries, such as the Argentinean Nanotechnology Foundation (FAN) in Argentina and the Spanish Information and Communication Technologies platform PLANETIC could be interested too.

European participants in the workshop in Curitiba considered the presented Latin American research to be of international standard, but missed the cooperation with industry from the early research stages onwards. This is common practice in their own research and helps to focus the research on practical issues. Capacity building in the Latin American research community should concentrate on bridging the gap between academia, industry and other stakeholders as well as networking to overcome fragmentation.

4.2.2 Funding for Science, Technology and Innovation

NMP-DeLA Community of Interest members recognized there is a need to improve coordination and longer term reliable funding strategies for nanotechnology. In addition, the Community of Interest recommended that the World Bank, IMF, and commercial banks, be made more aware of the potential of investing in nanotechnologies to contribute to their sectorial strategies. The awareness of policy makers and other stakeholders of nanotechnology should be raised and nanotechnologies should be included in regional development strategies. A feasible way forward could be if the policy makers participating in the NMP-DeLA project and CoI introduce the recommendations of this roadmap into their discussions about funding priorities with World Bank and IMF representatives.

Members recommend creating an EU-Latin American research programme for nano for health, energy and water. This should be done by combining funding for common EU-Latin American projects and partners from EU, national European and Latin American public sources. Relevant funding bodies have already been identified in annex 1. These funding bodies are then recommended to make available sufficient resources for conducting relevant research in LA in new industrial research, development and innovation projects.

4.2.3 Industry and Investment

Innovation can be targeted in different ways, according to NMP-DeLA Community of Interest members. Latin American researchers should promote innovation and technology transfer. A network of labs that are involved in nano research should be created to supported patenting and the publication of research results that have identified market impacts. Such networks should include pilot plant and manufacturing facilities, patent lawyers and technical schools.

Interviewed experts made the following recommendations for fostering manufacturing of nanotechnologies in LA:

- Support both an industrial base for manufacturing and processing of nano-enabled products, and a base for the production of the raw materials.
- Assess how new markets can be developed in LA and how existing products can be introduced to new markets. Consider what approaches must be taken to ensure investor confidence in the market and its long-term financial viability. Industrial applications of nanotechnology can be fostered by investment in infrastructure and human capital at universities, innovative companies and local production capacity.

According to a participant in the NMP-DeLA workshop in Chile, all nanotechnologies are developed in the North, not in LA or Africa. It is important to generate networks between Europe and LA to stimulate innovation in LA. In this regard, intermediary organizations should:

- create links between industries and researchers in NMP areas;
- create validation systems for methodologies and by-products of NMPs, standardized for the whole sector;
- organize visits to Europe (and LA) in order to better understand the experience suppliers in different countries.

European companies with offices in LA should communicate their best practices in nanotechnology innovation to Latin American business partners. In relation to this, the Materials Science and Engineering Expert Committee (MatSEEC) of the European Science Foundation (ESF) has recommended some measures to overcome the European gap between excellent science and industrial uptake by establishing European Technology Research and Validation Platforms and creating an 'Open-Access-Open-Innovation' European Technology Research and Validation Infrastructure Initiative (MatSEEC, 2015). Such a model could also be expanded to LA.

National initiatives

In **Chile**, technology transfer of nanotechnology from the national programme CEDENNA to industry is problematic. As in many countries, there are big cultural differences between industry and university, represented by how they deal with development time: the time horizons in industry are short and the focus is on concrete applications, while the time horizons in university are long and the results are uncertain. Furthermore, CEDENNA has adopted technology translation approaches to help companies understand the utility of new technologies being developed within universities.

4.3 Producing technologies and applications in the future

How can solutions, technologies and applications be produced in the future for generic developments related to nanoscience, nanotechnology, new materials and production technologies in Europe and LA with a view to fostering international cooperation? This includes solutions needed, timeframe for implementation and action steps (at national, EU and LA level) for developing the general capacity to innovate in LA.

4.3.1 Basic Research

It is important to realise that most of the research in LA is still in the basic research phase and that there is a lack of research equipment, infrastructure and disposables (chemicals and materials for experiments). An important element of the roadmap is therefore to focus on capacity building for research in nanoscience and nanotechnology in LA to create the conditions for nano innovation in the long term. The existing collaborations involving Latin American and European partners should preferably be consolidated and strengthened. In the short to medium term, cooperating researchers should be encouraged to submit proposals to EU Horizon 2020 calls[33] relevant to EU-Latin American cooperation in NMP as well as national funding of Latin American and European countries (see annex 1).
This is now being addressed by those LA countries which have not historically engaged significantly with EU researchers. For example, according to interviewed experts, Costa Rica intends to increase its cooperation with European partners in the next 3 to 5 years, especially in terms of energy, health and environmental remediation.

The arguments raised during discussions in the focus groups confirmed the lack of basic resources and infrastructures in LA necessary for nanotechnology researchers of the region to be globally competitive.
Researchers from more isolated regions (e.g. from the northern part of Argentina, which is a highly centralized country) or from smaller countries (e.g. Costa Rica) in particular suffer competitive disadvantages. In their research careers they have to cope with numerous constraints, such as serious limitations in research infrastructure and equipment and the lack of proximity to big enterprises. These countries and regions depend more than others on international cooperation as a means to substitute missing local infrastructure. Therefore they would welcome additional government support to maintain and extend such cooperation (including academia – enterprise networks).
In order to realistically cope with situations of scarcity of research infrastructure in LA it is inevitable that countries and states join forces. One concrete proposal, which was made in one of the focus groups, was to establish large shared resource centres in the region where specialized services can be acquired by individ-

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33 http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/ftags/international_cooperation.html#c,topics=flags/s/IntlCoop/1/1&+callStatus/asc

ual researchers or by research teams according to their specific demands. At this moment many small labs in LA are forced to either buy a complete suite of expensive equipment or do without. Having accessible, well equipped reference centres which deliver high quality services could empower those institutions to deliver faster and better results. However, not all participants agreed that establishing such big technology centres was a good idea. Some had poor experiences with such centres (e.g., lack of well trained technicians, limited working hours of technicians, limited possibilities to do one's own experiments). Nonetheless, all agreed that there is a need in LA for more and better ways of sharing and interchanging research infrastructure, whether this is in the form of big technology centres with improved services, associations of infrastructure networks or strategic matching of networks with specialized methods and equipment.

Another point which came out clearly in the focus group discussions was that national R&D priorities in nanotechnology are not consistently pursued in LA. Brazil, for example, has many defined research priorities for nanotechnology, but in practice the abundance of priorities leads to a loss of focus. There should be a political push towards stronger commitment to more carefully selected priorities. Or as one discussant put it: "make motivated choices based on quality and relevance" or in the words of another discussant "concentration where necessary, cooperation where possible." These priorities should of course be aligned with societal challenges of the specific region. More focus would help to use limited financial resources more efficiently and to break the Latin-American tradition of producing "cana" (conocimiento aplicable no aplicado) - not applied applicable knowledge[34]. Basic research is important, but no matter how basic it might be, it should have a vision of future application and societal impact. Impact should be planned at the beginning of every research project. This exercise should have the objective of producing solutions and products which are socially relevant, realizable (e.g. financially affordable) and culturally accepted.

It was strongly suggested that nanosafety should be made a research priority, as LA has a serious need to catch up on this issue. The development of new nanomaterials or nano-based technologies should be accompanied more strongly by studies on potential and effective risks and impacts which is especially important in the health, water and energy sectors. More risky research would also offer better demonstration opportunities for viable and secure nano-based solutions which would give incentives to policy makers and consumers to get involved or interested in products. In addition, discussants recommended that decision makers should launch a joint call for a global study on nanosafety and toxicology. The result of such a global study should be a uniform guideline, on the basis of very well characterized nanoparticles, which would include basic definitions and standards as well as assessments of long term toxicological effects and environmental impacts. It is not clear if these discussants were aware of the existing efforts coordinated by the OECD and ISO.

The enhancement of interdisciplinarity was named as another potential priority topic in nanotechnology research policy. Nanotechnology driven solutions will require complex interdisciplinary and multi-perspective solutions that must be supported.

[34] Term indicated by a participant of the focus group.

With regards to research output, all discussions reflected the wish to shift emphasis from incentives to publish to incentives to patents and manufacture. This however would entail a process of rethinking and rebuilding research cultures as well as the need for better support and guidance for researchers who are not familiar with requirements, rules and regulations of patent applications. At the same time funding bodies would need to show more tolerance with regards to time-lines for research outputs, because patent applications are more time consuming than publications.

A study published in PLOS ONE confirms that in some countries in LA, like Brazil, the number of patents remains low or is even decreasing in spite of steadily increasing numbers of publications. Chile is the only country in LA which has substantially improved its position in this regard. Asia, and in particular China and India, is on the contrary an emerging region, both in science and patents. The report also reveals that developed countries accumulate ever more patents and that global inventive effort is a highly concentrated phenomenon (Toivanen and Suominen, 2015).

On many occasions it was mentioned that knowledge and support structures for technology transfer are especially weak in LA. As a result the link between research, application of knowledge and societal benefits of technologies is weak as well. Researchers have identified a need for better training and better support in technology transfer and scaling up of R&D. At the same time industry–academia partnerships should be strengthened, as many industrial problems can be addressed by academia, and academic researchers can in turn benefit from the experience and perspectives of industry.

A topic which was debated strongly in the focus groups, and deemed highly relevant, was the issue of a clear definition of nanotechnology. Researchers struggle with vague and confusing definitions of their own research area. In the end, what is and what is not considered to be nanotechnology may determine the funding opportunities for a project or a product. As definitions are always purpose driven, the attempt to come to a common understanding failed already in a small group. The conclusion which was drawn in the focus group was that agreement on a definition between different stakeholders can only be found when it gets clear for which purpose the definition is needed. Provisionally it was selected as the most appropriate solution to have a very broad and flexible definition of nanotechnology which can be fine-tuned for specific application areas. Nonetheless, the discussion showed that the problem of definition is an emotional one amongst researchers which in the end may also have economic effects. [35]

4.3.2 Education and Training

In the short to medium term, the current lack of trained nanoscientists and nanoengineers could be addressed by lecturers in LA developing a model curriculum in nanotechnology in partnership with their Euro-

[35] It was not clear whether the participants were unaware of the developments in ISO and OECD to define nanotechnology (in a standardized way) and what its impacts are, or whether the issue was with those writing the specific call texts, not being clear about requirements and conditions.

pean counterparts. On the Latin American side, the existing NanoAndes[36] platform could be used to organise the community and disseminate teaching methods and materials. On the European side, the model curriculum developed in the EU funded project NanoEIS[37] could be used as a starting point to discuss international standardization.

In the focus group discussions it was suggested to include capacity building in nanotechnology as a priority topic in the NMP-DeLA roadmap. Excellent or well-trained experts and technical staff in nanotechnologies in the areas of health, water and energy are still few and far between in LA and the supply of high level education and training in these areas is geographically highly concentrated. However, there was no clear prioritization, e.g. for basic or higher education or for educating the public (using the media), the work force and employees of governmental institutions. All of these were considered equally important. There was a certain discord between the focus groups participants about the form of introducing more nano in education. In one focus group it was suggested to introduce a one-year post-graduate training course or to create specialized graduate programmes for nanotechnology in countries where these do not exist. Supply of nanotechnology courses and trainings is very unevenly distributed within LA and gaps need to be filled on the basis of an inventory of existing programmes. In another focus group it was agreed that a specialized nano post-graduate course was not necessary, because nanotechnology should rather be well integrated in existing curricula (e.g. in physics or chemistry). It was further mentioned that nanotechnology researchers should be better equipped with additional language skills, especially in English, as the lack of language proficiency remains a barrier in international cooperation. Education, awareness raising and communication to policy makers and the general public is also deemed important and can build upon existing initiatives including the South and Meso-American Research Centres for Fundamental Research[38], NanoAndes[39], NanoDYF[40] and ReLANS[41].

4.3.3 Policy and Funding for Science, Technology and Innovation

The World Bank has studied international STI partnerships and concluded that such partnerships have been promoted in an *ad hoc* fashion and with limited capacity, often operating in isolation from related donor activities in the same country in the same period, and not addressing the priority needs of the country. The WB has also proposed regional or international extension of existing national Inclusive Innovation Funds (IIF)[42].
According to Françoise Roure in a presentation in NMP-DeLA's workshop in Chile, the OECD Working Party on Nanotechnology has developed a roadmap for commercialization of nanotechnology. This follows a smiling curve: intangible activities add more value to a product than tangible activities (production). OECD STI

[36] www.nanoandes.org
[37] www.nanoeis.eu
[38] http://www.ictp-saifr.org/ and http://mctp.mx/index.html
[39] www.nanoandes.org
[40] www.nanodyf.org
[41] www.relans.org
[42] Source: UN Task Team 28:
http://www.un.org/en/development/desa/policy/untaskteam_undf/thinkpieces/28_thinkpiece_science.pdf

has developed indicators for nanotechnology published in October 2014 (OECD, 2014b). The problem is that these indicators are so heterogeneous, that they cannot be compared. Only indicators for publications and patents are available, not for production.

Policy makers from Europe and LA could strengthen the local capacities for innovation in nanoscience and nanotechnology by agreeing a common long term strategy and by pooling resources for common research and innovation priorities as part of the EU-CELAC policy dialogue.[43]
A survey respondent expects: *"In the coming years, competition [between European and] Asian countries will be very high, as many contracts are signed between LA and Asia. However the German Federal Ministry of Education and Research (BMBF) and maybe other countries give a clear, unambiguous signal that they want to develop their relations with LA universities."*

The focus group discussions showed that nanotechnology researchers are very well aware of structural barriers that hinder the full exploitation of market opportunities and the social deployment of nanotechnologies, because they experience them in their daily routine. Nevertheless, they feel that their concerns and recommendations are hardly heard or recognized at the political level. To name just one concrete example, researchers feel isolated when they need to import certain equipment or drugs for their research and are confronted with unclear national legislation. Apart from financial support, researchers expect more political and legal support from government bodies, especially when it comes to limitations that lie within national systems of regulation. A prerequisite for change is to enhance the dialogue (or build from scratch) between decision makers, competent authorities and researchers. Low networking and cooperation in nanotechnology was identified as a major weakness in LA by the focus group discussants. Networking barely passes institutional borders. European funded cooperation projects have served as catalysts in selected cases to bring researchers and companies (or other actors), which have not cooperated before, together in teams. Much more coordinated networking will be necessary in the future.
Various means exist to organize a continuous exchange between different actors, e.g. the formation of disciplinary groups with representatives of the triple helix which could identify very specific opportunities, the nomination of intermediaries who conciliate between stakeholder groups, multi-stakeholder workshops, web-based discussion platforms, etc. A feasible first step in many countries might be to set up an open web-based nanotechnology platform where all stakeholders can register and which would function as a "who is who" for nanotechnology.
Foremost, LA countries lack (in most cases) integrated national nanotechnology strategies which would allow for more balanced developments of nanotechnology capacities. The example of Mexico illustrates this imbalance: whereas in the northern State of Nuevo León there exist internationally recognized nanotechnology incubators and training courses, in the south of Mexico the concept of nanotechnologies is widely un-

[43] http://ec.europa.eu/research/iscp/index.cfm?lg=en&pg=latin-americ-carib-3

known among citizens. At the same time the South faces bigger societal challenges related to water and energy and could benefit even more from improved technological solutions.

Some main critical points arose in the focus group discussions with regards to the definition of national nanotechnology strategies. These points addressed the WHO (Who should formulate and monitor such a strategy?) and the WHAT (What should be at the heart of such a strategy?). Concerning the WHO-question it was agreed that the strategy development should be done in a circular process and involve all stakeholder groups and the public (from the definition of goals to the monitoring of the implementation and the assessment of impacts). The WHAT-question was more controversial in the sense that one suggested approach was to concentrate national resources on broad strategic areas (such as water treatment) and another approach suggested the identification and promotion of very specific “killer applications” which would be “a very powerful tool for communication and outreach and for convincing people and policy makers of the benefits of nanotechnology”. In the end both approaches are valid. Overall there was strong agreement that a clear prioritization (in alignment with national/local societal challenges and the principles of responsible research and innovation) needs to be at the heart of a realistic national nanotechnology strategy. The next step would require strong instruments (policies) which promote, monitor and evaluate the progress of implementation.

Another key recommendation, which focus group participants directed at decision makers, was to invest more resources into information and awareness raising campaigns on nanotechnology. Consumers in LA are not aware of nanotechnology products that are already on the market, and they have unrealistic expectations regarding what the technology can and cannot offer at this moment. The younger generation in particular needs to be educated as the next generation of conscious and responsible consumers.

With regards to attracting private sector investment in nanotechnology research, the participants of the focus groups were of the opinion that the continuous change of authorities and systems, and ensuing political and economic instability, makes long term planning difficult and reduces the willingness of entrepreneurs to invest in the region. There is probably no easy solution to this problem, but nevertheless it does remain a systemic barrier that hinders private sector funding of research.

One means to initiate collaborations (also with the private sector) could be to implement seed grants (which could be for exploratory research) or to provide funding for the brainstorming of larger projects. Another idea was to launch special calls for specific local societal challenges.

4.3.4 Industry and Investment

The Strategic Research and Innovation agendas of the ETPs define the priorities in Horizon 2020 calls. Stakeholders including Latin American experts and companies can influence this strategy by joining the ETP Nanofutures that has created an evolving roadmap. The Nanofutures roadmap aims to promote European industrial leadership in nanotechnology. It targets seven market driven value chains: Lightweight Multifunctional Materials and Sustainable Composites, Nano-Enabled Surfaces for Multisectorial Applications, Structured Surfaces, Functional Alloys, Integration of Nano, and Infrastructure for Multiscale Modelling and Testing. The roadmap foresees short, medium and long term actions in each of these value chains in the period 2012-2020 with an estimated total public-private funding of €1.5 billion. Latin American research organizations and companies are welcome to join Nanofutures.[44] In 2015, Nanofutures updated its roadmap, focusing on four value chains (VC) and proposing four pilot lines. The value chains are:

1) Nano and micro printing for industrial manufacturing
2) Nano-enabled, depolluting and self-cleaning surfaces
3) Manufacturing of powders made of functional alloys, ceramics and intermetallics
4) Lightweight, multifunctional materials and composites for transportation.

The pilot lines are:

1) Nanostructured surfaces and nanocoatings (VC2)
2) Manufacturing of multifunctional materials with nano-enabled customised thermal/electrical conductivity properties (VC4)
3) Printed microfluidic MEMS and biological applications (VC1)
4) Non-mainstream Micro-Electro-Mechanical Systems and Architectures (VC1).

As VC3 focuses on materials to be taken up in the other three value chains, no pilot line is foreseen for this value chain (Nanofutures, 2015).

According to Niccola Tucci in his presentation during the NMP-DeLA workshop in Chile, European Innovation Partnerships (EIP) and European Technology Platforms (ETPs) could be used for stimulating involvement of SMEs (also from LA) in EU funded research. EIP is a new instrument for coordinating EU, national and regional innovation. The aim is to cut the lead time by implementing steps in parallel. A relevant EIP is the EIP Smart Cities and Communities, which is coordinated by a high level group that is closed, but has a stakeholder platform that is open to new participants. The partners are cooperating to develop a common strategy and interested parties can join the smart cities platform to lobby for their ideas. The EIP could be a model for Latin American networking.

National interests

In some Latin American countries there is a need to develop new methods for stimulating technology transfer from academia to industry. For example, in **Chile**, companies are decreasing their innovative capacity. There is a need for a transformation to a more diverse and sustainable economy through investing in R&D and human capital. Chile could benefit from a Smart Specialization programme, as fostered by the EU, taking into account its limited public funds for innovation at national, meso-regional and regional level.

Researchers who participated in the focus groups strongly believe that much more effort needs be made in LA to trigger the creation of spin-offs and start-ups. This could include e.g. support for the application of patents or legal advice for the protection of intellectual property. More effective technology transfer models

[44] www.nanofutures.eu

were also strongly demanded. Common public-private nanocentres and common industry-academia initiatives were proposed as means to concentrate efforts on most relevant problems. For the application of nanotechnologies in the water and energy sector, there was a high level of agreement between participants that the cost of nanomaterials must be reduced in LA, since at present, nanomaterials are purchased from China. It will be a serious challenge to produce nanomaterials locally for a price that allows broad application in viable solutions for water treatment or for other societal challenges. This would probably entail more resources for material sciences. As a means to attract private investment it was suggested that more demonstration activities should be funded in order to excite industry and consumers for new nano-based solutions which improve existing products and processes. In this context it was stressed however that a realistic view on the technology's possibilities has to be transmitted in order to avoid false expectations. Ultimately it was said that the future lies in sustainable processes and equipment.

4.3.5 Ethical, Legal and Societal Aspects

As argued in the first NMP-DeLA Ethics and Gender Report, European-Latin American cooperation in nanotechnology should be targeted to the new United Nations Sustainable Development Goals (2015-2030) that are expected to be adopted by the UN General Assembly in September 2015. It also should respect the guiding principles in the EU policy for Responsible Research and Innovation (RRI) in Horizon 2020 and those formulated by the Argentinean CECTE and possibly other Latin American ethics councils. The six key elements for the EU RRI are: Public engagement, Gender, Science education, Open Access, Ethics and Governance. The CECTE is working on propositions for responsible nanotechnology, based on its more general propositions for responsible science.[45]

Of relevance to this area is the EC recommendation on a code of conduct for responsible nanosciences and nanotechnologies research (EC, 2008)[46], and the Report on the quality criteria of Good Practice Standards in RRI which was developed in the framework of the RRI Tools project.[47] The quality criteria presented in the report may be used to consider how research and innovation practice could be designed in order to be more responsible. Consultation among 441 respondents in 27 European countries revealed that stakeholders have little knowledge about RRI, which is seen as an abstract concept. Stakeholders attribute responsibility mostly to others, not to themselves. Attitudes are mainly risk averse and focused on the short term. However, RRI tools and training can help improve knowledge and skills of the stakeholders, including who they should be addressing. Opportunities include bringing science and society closer together and improving the quality of innovation. The conclusion was surprising: there is considerable enthusiasm and optimism about RRI and a belief that it should be a serious transformative activity rather than ticking boxes. It is an opportunity to take a longer view and foster a paradigm shift towards normative goals and values. The web-based repository of

[45] http://www.cecte.gov.ar/

[46] European Commission, DG Research (2009): Commission recommendation on a code of conduct for responsible nanosciences and nanotechnologies research, Brussels

promising RRI practices may also be used in EU-Latin American cooperation on nanotechnology, materials and production technologies from August 2015 onwards. An online self-assessment tool for researchers to support their reflection on responsible research and innovation will also be implemented. [48]

According to Françoise Roure (during presentation in the NMP-DeLA workshop in Chile), nanotechnology is a platform technology for emerging nano-enabled and nano-enhanced products and systems. There are two game-changers for nanotechnology commercialization:

1) a uniform descriptive system for materials at the nanoscale, according to a white paper published by the International Council for Science (ICSU) and the Versailles Project on Advanced Materials and Standards (VAMAS), that is open to international cooperation. (CODATA-VAMAS, 2015)
2) going beyond the precautionary principle by introducing the RRI concept. A mandatory Sustainable Impact Assessment (SIA) mechanism should be introduced before signing trade agreements to avoid commercial disputes.

The experiences of participants in the focus group discussions showed that dealing with legal issues related to research activities is very time consuming and annoying for nanotechnology researchers in LA. In most Latin American countries there is a severe lack of (progressive) regulation in Nanotechnologies in all aspects (health, environment, safety, etc.) and current norms seem to be extremely outdated and/or not adapted to the national or specific case. Researchers felt that employees of national regulatory bodies in LA are often poorly informed about the latest developments in nanotechnology regulation or that they do not have the capacities to keep track of international standards. Researchers in smaller LA countries, which rely heavily on import of equipment, feel overwhelmed with a lack of clarity of rules and regulations. As one focus group participant put it: “While you may have an antibody waiting in your lab you have to struggle with national import regulations and you risk losing your work.” High-quality periodic training might be a means to guarantee that regulatory agencies are more responsive and well equipped with up-to-date information.

It was also considered important to include researchers/academia as well as social scientists in the development of up-to-date norms and regulations, and to acknowledge regulation as being a political and not just technical process. It will, however, require special incentives to attract researchers for such an involvement, because according to current systems they are primarily evaluated by their publication output. Once norms are defined, the second challenge is to make them binding and introduce instruments to supervise their compliance. It was suggested that Risk Analysis and Technology Assessment (RATA) should be an integral part of research programmes.

Intellectual Property Rights (IPR) were identified as another especially sensitive matter related to legal aspects of nanotechnology. Due to a general lack of Non-Disclosure Agreements (NDA) and Material Transfer Agreements (MTA) in LA as well as the fact that most researchers are ill informed about IPR standards, the potential of knowledge transfer is not being fully exploited.

[47] For downloaded at www.rri-tools.eu/workplan-deliverables, WP1 Deliverables
[48] C.f. presentation Ilse Marschalek, NMP-DeLA workshop Curitiba, Brazil, 28-29 May 2015, www.nmp-dela.eu

Latin American countries seem resistant to become party to the Patent Cooperation Treaty (PCT). This puts researchers in the position that they have to make individual arrangements with big institutions or companies, which is burdensome and slows down the application of patents.

Last, but not least, it needs to be stressed that LA countries are at very different stages concerning their progress in ELSA and ongoing efforts (such as Brazil being a partner in NanoREG) need to be acknowledged.

5 Module: Solutions for Health

5.1 Nanomedicine Platform Technologies

5.1.1 State of the Art

How is NMP deployed (now) in the context of societal challenges in the field of health for nanomedicine platform technologies developed in Europe and LA with a view to fostering international cooperation? This includes existing solutions identified for improving the capacity to develop innovative nanomedicine platform technologies in LA, and their stage of development.

5.1.1.1 Nanomedicine Research

General applications of nanotechnologies for health are within the fields of nanobiotechnology, nanomedicine and nanodevices (Frost and Sullivan 2008). According to the European Technology Platform on Nanomedicine (ETP-Nanomedicine), nanomedicine is the application of nanotechnology to achieve innovation in healthcare (ETP-Nanomedicine, 2014).

It uses nanometre scale materials and nano-enabled techniques to diagnose, monitor, treat and prevent diseases. These include cardiovascular diseases, cancer, musculoskeletal and inflammatory conditions, neurodegenerative and psychiatric diseases, diabetes and infectious diseases (bacterial and viral infections, such as HIV), and more (Filipponi and Sutherland 2013:157).

According to Filipponi and Sutherland (2013), the potential contribution of nanotechnologies in medicine is extremely broad and includes: new diagnostic tools, imaging agents and methods, drug delivery systems and pharmaceuticals, therapies, implants and tissue engineered constructs. As many biological mechanisms in the human body are also on the nanometre scale they allow nanoparticles and nanomaterials to potentially cross natural barriers to access new sites of delivery (directly to the targeted organ/tissue) and to interact with DNA or small proteins at different levels, in blood or within organs, tissues or cells (ETP-Nanomedicine, 2014). Nano-enabled medicine is comprised of new applications for healthcare, in which nanomaterials and nano-electronics are being used for targeted drug delivery or for early detection of diseases (a combination of therapeutic treatments and early diagnosis of illnesses, known as theranostics).

In LA, several research groups are working on nanotechnology for health applications according to our bibliometric analysis. **The main findings obtained through the analysis of the evolvement of publications and co-publications are**:

- Research on nanomedicine has increased steadily since the mid-2000s. However, the growth is not the same for all countries and between different areas of nanomedicine, and some areas are still at an early stage of development. The most developed area, according to the number of publications, is drug delivery.

- The data shows a strong concentration of publication output in Brazil, followed by Mexico and Argentina. The Universidade de São Paulo, followed by two other Brazilian universities and then the Universidad Nacional Autónoma de Mexico are the most productive research institutions in terms of nanomedicine publications.
- Co-authoring is another important trend. According to Scopus data, approximately one fifth of health related nano-publications from Latin American countries involve collaboration with countries in Europe. Spain, France and Germany stand out as the most common EU partners for LA co-publications. The most significant collaborations are Brazil with France, Portugal and Poland. Also of note are the collaborations between Chile and Spain, as well as the latter with Cuba, Argentina, Mexico and Uruguay.

Each country has research groups working in nanomedicine, with some specialization on different specific areas:

- Brazil has funded 37 nanotechnology research networks since 2001, out of which 14 have been addressing issues of nanomedicine, mainly in the areas of drugs and therapies and drug delivery;
- Mexico has several groups working on nanomedicine distributed in public universities, national research centres, hospitals and research centres of the Ministry of Health. The main research themes are materials for diverse applications in nanomedicine, drugs and therapies, and drug delivery;
- Argentina has funded four nanotechnology research networks since 2004; one of them is dedicated to health. The main research topics are drug delivery and tissue engineering;
- Chile has some research groups headquartered in the main universities, mostly addressing drugs and therapies research;
- Colombia´s research groups have a strong focus on nanotechnology applied to cancer research;
- Uruguay has a small group working with nanomedicine, investigating a number of areas (Invernizzi et al, 2015).

At a national level, the Argentinean Association for Nanomedicine (NANOMED-AR) is coordinating research on nanomedicine for drug delivery, organ regeneration and diagnostics.[49] They are establishing contacts with other Latin American experts in a Latin American Association, in close cooperation with the International Society for Nanomedicine. This forms a platform where national and regional associations of scientists meet. In Europe, the European Association for Clinical Medicine (CLINAM)[50] and the European Society for Nanomedicine[51] represent the regional branch of this International Society. The European Technology Platform ETP-Nanomedicine is the main public-private network bringing together all European stakeholders including gov-

[49] www.nanomed-ar.org
[50] http://www.clinam.org/
[51] http://www.esnam.org/

ernment, research and industry in this field and has produced (and regularly updates) the EU's nanomedicine strategy.[52]

National and institutional priorities in research

The research areas covered by interviewed members of the NMP-DeLA Community of Interest target the following generic applications:

- Platform technologies for drug delivery: The Universidad Pointificia Bolivariana de Medellin (UPB Medellin), Colombia studies cardiomyocytes at the subcellular level and develops scaffolds for drug delivery together with partners in Italy and Mexico. At the Fundación Instituto Leloir, the Laboratory of Molecular and Cellular Therapy (LMCT) in Argentina is working on gene therapy together with MINCYT, University Valparaiso in Chile, and Inter-American Development Bank (IDB). The Bioengineering Department at the National University of Tucumán, in Argentina is working on liposomes for drug delivery together with Fundación Instituto Leloir in Argentina. The National Nanotechnology Laboratory (LANOTEC) in Costa Rica works on bionanotechnology, biosynthesis, DNA nanotechnology for controlled release, and antimicrobial nanomaterials. CIBER in Spain works on translational research, prototype development for nanopharma in a network of biomedical research centres in Spain and could serve as an example for similar centres in Latin America.
- Platform technologies for sensors and diagnostics: UPB Medellin is developing textile nanofibres for wearable sensors for measuring biopotentials for health monitoring in cooperation with partners in Mexico and Italy. The Bioengineering Department at UNT is working on biosensors for health and agriculture. They cooperate with partners in Spain and universities of Leipzig and Munchen, in Germany. The National Institute of Industrial Technology (INTI) in Argentina works on magnetic nanoparticles, gold, antibodies, and memory devices using microfabricated TiO_2 applied in a technology platform for *in situ* detection of diseases in humans and animals in point of care applications.
- Platform technologies for regenerative medicine: The Bioengineering Department at UNT is working on Biomaterials in tissue engineering for bone applications. The EU funded project SMILEY has applied new bio-inspired processes to develop smart multifunctional constructs for tissue regeneration. Numerous EU-funded projects (i.e. AUTOBONE, TEMPLANT, OPHIS, MAGISTER) have been developing new solutions for unmet clinical needs in regenerative medicine and theranostics.
- Latin American specialities such as the exploitation of extremophiles found in Antarctica and fungi for synthesising quantum dots (Universidad Andres Bello, Chile). This group has the infrastructure to follow the environmental fate of nanoparticles through the food chain. 80 Nanoscientists in Uruguay work in Polo Tecnologico Pando &, Inst.Pasteur, Montevideo on diagnosis, analysis, treatment, encapsulation for drug delivery, collagen matrix with encapsulated drugs for tissue repositioning of burned skin.

[52] www.etp-nanomedicine.eu

5.1.1.2 Funding for nanomedicine

The ETP-Nanomedicine estimates that the European Union has invested about 550 million euros in nanomedicine related projects under the 7th Framework programme for RTD, in 85 projects in the NMP thematic programme and 31 in the Health programme. In addition, relevant projects have been funded under other programmes. 40 projects are ongoing.[53]

The qualitative study carried out in the framework of the NMP DeLA project (Invernizzi et al, 2015) indicated that all countries have oriented public funding to nanomedicine, but only data for Brazil and Mexico illustrate a comprehensive picture of these matters. In the case of Brazil more than one third of the nanotechnology projects granted to companies, with non-refundable funds, were directed to promoting nanomedicine. Furthermore, we determined that around one third of the funding directed towards research networks was secured by nanomedicine-related projects. In this context it is worth noting that the Brazilian Ministry of Health allocated funds directly to this area. In Mexico a study of several calls for research showed that around 5% of the budget was aimed at nanotechnology research and out of that only 10% was directed to nanomedicine.

5.1.1.3 Pharmaceutical and Medical Devices Industry and Investment

An extract of a list of applications compiled by Aydogan-Duda (2012c, cited in the NMP-DeLA specific roadmap for health) demonstrates the general applications of nanotechnologies for health. They includes targeted drug delivery for reducing side effects and damage to healthy cells, tissues and organs. Relevant nanomaterials include quantum dots (Qdots), which can be coated with biomolecules to identify the exact location of cells (e.g. cancer) in a body; nanoparticles that deliver drugs directly to cells to minimize the damage to healthy cells; nanoshells that can generate heat from infrared light to destroy cancer cells with minimal damage to healthy cells; nanotubes that can be used to repair broken bones and to provide a structure for new bone material to grow; nanosilver and other antimicrobial nanoparticles that are already applied in treating wounds and preventing infections. Nanoparticles are also enabling simple, inexpensive diagnostics.

According to the mapping carried out in the framework of the NMP DeLA project (Invernizzi et al, 2015) nanotechnology is researched and developed by some companies in LA. Brazil has the largest number, 30 in the area of pharmacy and health, which have received public funding to enhance R&D activities. In Mexico, only 2% out of the 101 companies with activities on nanotechnology are looking at medical applications. No information was available for the other countries.

Current manufacturing of nanotechnologies for health in LA is limited. NMP-DeLA Community of Interest members mentioned some examples. Two Brazilian companies have introduced nanocosmetics onto the market and the Brazilian Agricultural Research Company (EMBRAPA) has developed an electronic tongue for food quality measurements.

Patenting is underdeveloped across LA. For example, in January 2012, the Brazilian patent office (INPI) published an analysis of Brazilian inventors who have patented nanotechnology inventions worldwide and an analysis of global patents in nanobiotechnology. Priorities in global nanopatents by Brazilian inventors include five patents in medicine/biotechnology (Instituto Nacional de Tecnologia, Universidade Federal Fluminense, USP, Cristiano Alberto Ribeiro Santana, Fundacãp de Amparo à Pesquisa do Estado de São Paulo) and two in cosmetics (Chemyunion Quimica LTDA, Natura Cosmeticos S.A.).
Nanobiotechnology patents applied for in Brazil mainly target pharmaceuticals, cosmetics and diagnostics applications. Most nanobiotechnology patent applications in Brazil originate from the USA (30%), France (16%) and Brazil (15%). The other 39% originate from 20 other countries.

5.1.2 Nanomedicine Good practices and Recommendations

What are good practices and recommendations for nanomedicine platform technologies developed in Europe and LA with a view to fostering international cooperation? This includes national and regional examples of actions for up-scaling innovation in these platform technologies.

5.1.2.1 Nanomedicine Research

At a general level, a member of the NMP DeLA Community of Interest recommends that Latin American research policy makers should set the priorities in research on nanotechnology for health and look for complementary European expertise. It is important to focus on high impact problems in LA rather than more general diseases (e.g. cancer, autoimmune diseases). From the perspective of a Latin American member there is a need to invest in databases of epidemiological records and improved quality of the records.

5.1.2.2 Policy recommendations

According to a community member, a database of key organizations should be created to support innovation in the Latin American health system. This should include national/multinational pharmaceutical/biotechnology companies interested in nanotechnology in therapy and diagnosis, raw materials suppliers, and organizations that manage supply chains, in addition to research actors from hospitals, institutes, and universities. Awareness of nanomedicine should be raised in the medical sector by presenting the latest advances in diagnostics and therapies with nanomaterials and by providing of training, capacity building, etc.

5.1.2.3 Pharmaceutical and Medical Devices Industry and Investment

Good practices: At a general level, innovation and technology transfer in nanomedicine can build upon the existing biotechnology sector in LA (Argentina, Cuba, Mexico, Chile, Colombia) and on the experience of

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[53] http://www.etp-nanomedicine.eu/public/about-nanomedicine/european-funding

foreign companies of Latin Americans returning from the diaspora. For example, an Argentinean researcher who participated in the discussions has prior experience in setting up a start-up in biotechnology and in integrating a start up in a big cluster of a pharmaceutical company in the USA.
Brazil and Argentina have elaborated a common funding strategy in nanomedicine. This model could be followed by other countries.

Recommendations:
International financial institutes like the World Bank, and the International Monetary Fund (IMF) are developing investment programmes in Latin American countries. Projects supported by these institutions frequently contain a description of the application domain, like energy, water and medical applications, but not on nanotechnologies or NMPs. For example, the World Bank Group "provides financing, state-of-the-art analysis, and policy advice to help countries expand access to quality, affordable health care, protect people from falling into poverty or worsening poverty due to illness, and promotes investments in all sectors that form the foundation of healthy societies."[54] This could be used to fund studies related to deployment of nanomedicine.
NMP-DeLA community members recommend contributing to technology transfer in nanomedicine. In the short term Latin American researchers want to learn from experienced partners in other countries. In the long term they should focus on niche markets according to European respondents interested in cooperating with Latin America.
On a more abstract level, it is necessary to develop a culture of innovation in LA in order to absorb technologies developed in Europe for deployment in LA. From a Latin American perspective, this should be done through the following steps:

- Change the culture of work and devise the means to build a new model for performance in the interest of time *versus* cost analysis that is significant to investors, stakeholders and partners.
- Build a consensus on quality in the field of nanotechnology at every level of R+D (target validation, identification of drug/diagnostics candidates, building a pipeline, product development, supply chain, marketing)
- Develop the concept of efficiency, and added value of product development.

5.1.2.4 Biomedical Ethics and Responsible Research and Innovation

Good practices mentioned by community members include the following:

- Social scientists in the United States of America and Europe have established good practices in discussing the social dimension of nanotechnology (reviewed in Malsch et al, 2012).
- The ETP-Nanomedicine has an nanoethics committee, which discusses how to integrate ethical aspects in the calls related to nanomedicine projects in Europe.

[54] http://www.worldbank.org/en/topic/health

- A good strategy for communication about nanotechnology has, for instance, been developed by the NanoBasque Agency at the Basque Country. One of the core activities is dissemination and communication of nanotechnology activities, and one of the targets is wider society. In Argentina, a number of individual organizations protect patients with HIV, hepatitis C virus (HCV), cancer, renal, cardiovascular, neurological, endemic infectious and other diseases. Ethical aspects of patenting can be improved by raising awareness of the impacts of pro-innovation incentives and market distortions caused by IP owners.

Recommendations on legal aspects:

- Governments and organizations working on legal and IP issues in Latin America should develop rules on industry-university cooperation. Unified standards on contractual issues between Latin American and EU partners are also needed. A specific recommendation, due to the nationality of the informant, is that the Argentinean government should join to the Patent Cooperation Treaty (PCT Treaty), invest in infrastructure and equipment and offer investment for technology transfer. More studies should be done on the legal limitations for patenting and ethical concerns of nanotechnology-based patents for health. The Brazilian Innovation Law, which governs industry-public university partnerships as well, was cited as an example that could be followed by other countries.

Nanobiomedical ethics recommendations:

NMP-DeLA community members recommend creating a network of correspondents in the field of ethical aspects of nanomedicine applications in Latin American countries, in order to have a community of people dealing with similar challenges. This network should include regulatory scientists and physicians, based on their commitment to follow excellency, bioethical standards and/or take policy/political stands. The network should be supported for the longer term. Knowledge and political proposals should be shared on how to handle social aspects of nanotechnology.

National recommendations for Argentina

Communication recommendations:

Transparency and clarity should be present in communications from scientists about nanotechnology. There should be a common global agreement on the message. As a matter of example, MINCYT in Argentina should develop a communication strategy including stakeholder meetings, conferences with leading academics and generate publications in Sunday magazines of newspapers.

Targeting local needs, from the perspective of Argentinean respondents:

The needs of the local population may be targeted by involving, for example, the Instituto de Efectividad Clínica y Sanitaria (IECS), an academic and independent non-profit institution created to improve the efficiency, equity, quality and sustainability of healthcare services and systems in LA, and Red Cochrane Iberoamericana (RCIB), an international non-profit organization whose purpose is to maintain and disseminate systematic reviews and meta-analysis of the literature to facilitate clinical decision making and health reviews.

NMP-DeLA community members recommended that a wider network of stakeholders in nano for health be engaged. This should involve government and private interest in issues of health, including non-profit foundations/organizations, such as “Mundo Sano” in Argentina, epidemiology vigilance institutions such as IECS, which evaluate population differences in non-transmissible diseases (such as Genocan), as well as Ministries of Health.

The question of how to address inequalities and discontinuities in regional health governance should be the subject of research for a specialized team of health consultants with health brokers and advocates. It is important to involve patients in discussions on nanomedicine, but there are for example no “patients safeguard” or “special interest” organizations oriented to medical needs and practice in Argentina, according to some. Medical doctors should be informed about nanomedicine, according to another community member.

5.1.2.5 International Cooperation in Nanomedicine

Recommendations: by 2025, a common funding strategy should be elaborated in LA for nanomedicine. It would be useful to have similar programmes in all of LA with a common interest and a common policy to determine that the money will be granted to specific priorities. The biggest challenge will be to create a programme that is independent from the economic and political situation of each country.

At a bi-regional level, nanotechnology should be included in the EU-CELAC policy dialogue, with the creation of a specific working group on nanotechnologies, which would be transversal. The structure of such working groups is presented in the bi-regional project ALCUE-NET.[55]

5.1.3 Producing technologies and applications in the future

How can solutions, technologies and applications be produced in the future for nanomedicine platform technologies developed in Europe and LA with a view to fostering international cooperation? This includes solutions needed, timeframe for implementation and action steps (at national, EU and LA level) for developing the nanomedicine platform technologies in LA.

5.1.3.1 Nanomedicine Research

In the short to medium term, existing European networks are opening up to international partners, e.g. the European Nanofutures platform is inviting contributions to its new nanoroadmap under development.[56] Fur-

[55] http://alcuenet.eu/policy.php
[56] http://nanofutures.eu/

thermore, the ETP-Nanomedicine is considering opening up to third countries, and has a bilateral agreement with Argentina as the first test case.[57]
From the Latin American perspective, the Argentinean Association for Nanomedicine is taking the initiative to establish a Latin American Association for Nanomedicine as a regional member of the International Society for Nanomedicine.

The starting point for nanotechnology strategy for health applications in LA should be building capacities in basic and applied research in the short to medium term.
Besides targeted diseases, the research undertaken by NMP-DeLA community members may in the future be applied for the following:

- Fluorescent labelling of biological macromolecules such as therapeutic antibodies
- Asthma and allergies which have a higher incidence rate in LA
- Cardiovascular diseases
- Rehabilitation (e.g. land mine victims)

In particular, German research on drug targeting with dendritic polymers can be adapted to applications for the fluorescent labelling of biological macromolecules like therapeutic antibodies. Austrian allergy research can be adopted to understand the higher incidence rates in Peru and Brazil. The local needs should be the starting point in any collaboration. Colombian nanobiomedical research may be applied to cardiovascular diseases and rehabilitation provided the research infrastructure can be built up and technology transfer skills specific for healthcare markets can be acquired. Spanish expertise in technology transfer and innovation could contribute to a common long term strategy for this. UFF in Brazil is setting up a biotechnology laboratory looking for research directions and UNT in Argentina is interested in setting up an incubator. Since these initiatives are only taking off, there is ample opportunity for targeting the research agenda to common interests of these organisations and international cooperation partners.

5.1.3.2 Pharmaceutical and Medical Devices Industry and Investment

NMP-DeLA community members perceive different market opportunities for nanotechnologies in LA. On a general level, existing industry in LA (such as biotechnology companies) may, in the short to medium term, be used to reinforce connections of nanomedicine with the healthcare market. However, it will be necessary to create industrial capacity for manufacturing of nanotechnology enabled products in the long term.
It may be worthwhile exchanging experiences with the Transnational Translation Hub fostering translational medicine initiated by the ETP-Nanomedicine. This will start with three Nanomedicine Pilot Programmes funded under Horizon 2020 under negotiation: ENATRANS, NANOFACTURING and NANOPILOT[58].
In this context, several niches were identified by Community of Interest members:

[57] www.etp-nanomedicine.eu
[58] http://www.etp-nanomedicine.eu/public/about-nanomedicine/nanomedicine-pilot-lines/nanomedicine-pilot-programmes

- A company that develops and distributes raw materials and polymeric products in LA could be useful to researchers because this will reduce time for shipping chemicals to research labs in LA.
- In Colombia, stents and devices for drug delivery can be brought to the market provided the inventors improve their technology transfer methodology that is adapted to the peculiarities of the Colombian healthcare market. They are learning from partners in the USA and Mexico.
- In Argentina, a start-up biotechnology company has been set up in the field of gene therapy using anti-body products of Llama origin. The primary target is cancer, but the platform could be adapted to other diseases. The company is looking for international partners.
- An Argentinean university has plans to set up an incubator for glucose biosensors, nanostructured electrodes and implants with a nanostructured coating.
- CONICET is interested in technology transfer of a number of nanotechnology inventions they have funded. CENTI in Portugal offers expertise on technology transfer of nanotechnology.

5.1.3.3 Biomedical Ethics and Responsible Research and Innovation

Opportunities for contributing to responsible research and innovation in the field of NMP are two-fold: in organizing dialogue about these issues and in targeting projects towards improving societal benefits. The ETP-Nanomedicine already offers a platform for elaborating questions and answers in the related grey zone of Ethical, Legal and Social Aspects (ELSA) of nanomedicine. An example is the discussion about the ethical, social and environmental aspects of nanomedicine coming from various EU projects (see for example a list in Annex 2 and experiences of Institut Pasteur in this field, when implementing nanomedicine. There is interest in extending this platform to Latin American partners. Furthermore, the question of how to make sure that the benefits of the research can be shared equitably with populations that do not have access to new medicines is included in Horizon 2020 calls.

National issues

The French government is concerned about stimulating converging technologies for Artemisinin (anti-malaria drug) and dengue in order to lower production costs and increase the supply to a larger segment of the global population. They also stimulate the industrial deployment of nanotechnologies and synthetic biology in the Territories, for global challenges such as water purification (Roure et al, 2014).

In Argentina, there is academic interest in a political strategy that will support the implementation of new technologies and at the same time ensures societal acceptance of these technologies through engagement with wider society. This should focus on innovation in nanobiosensors as well as on nanosafety.

5.2 Tropical Neglected Diseases including Tuberculosis

5.2.1 State of the Art

How are NMPs deployed in applications targeting tropical neglected diseases developed in Europe and LA with a view to fostering international cooperation? This includes existing solutions identified for improving the capacity to develop innovative pharmaceuticals and medical devices targeting these diseases in LA, and their stage of development. In this roadmap we focus on those diseases for which nanotechnologies may offer solutions.

5.2.1.1 Research on nanomedicine for tropical diseases

In general, few examples exist of research on nanomedicine targeting tropical diseases, e.g. diagnostic solutions specific to tropical diseases can be exemplified by the PodiTrodi project, which aims to develop integrated point-of-care diagnostic solutions for tropical diseases and is testing various types of nanostructured materials for the sensors (Tukiniemi 2013).

Some other examples of applications of nanomedicines for tropical disease therapies are presented by Look et al (2010) and in the EU-funded BERENICE[59]projects as well in current projects at Oswaldo Cruz Foundation (FIOCRUZ).These include therapies and diagnostic tools for HIV/AIDS, Hepatitis B and C, Leishmaniasis, Tuberculosis, African trypanosomiasis, Chagas disease, Lymphatic filariasis, Schistosomiasis and Malaria. Details are included in the NMP-DeLA specific roadmap for health.

As a result of the mapping of deployment of nanotechnologies for health (Invernizzi et al, 2015) we could not identify significant research, by means of bibliometric studies, addressing the topic of tropical diseases and scientific cooperation between LA and Europe. On the positive side, some international cooperation networks already exist. In particular the SABIN Institute hosts the Global Network on Neglected Tropical Diseases (NTDs)[60]. The US National Institute of Allergy and Infectious Diseases (NIAID) could also be open to international cooperation with European and Latin American partners.

The interviews revealed that several NMP-DeLA Community of Interest members are working on nanotechnology for tropical diseases in international cooperation. For example, at the Paris Lodron University in Salzburg (PLUS), the Immunology and Allergy Division at the Department of Molecular Biology is working on nanomaterials in medicine and nanodrug delivery for allergy therapy. This can be applied to selecting active drug compounds through the effect on the immune system. They already have Brazilian contacts. In the project EULANEST, nanomedicines are being developed for topical treatment against Leishmaniasis in cooperation with partners from Argentina and the University of Berlin. The Royal Institute for the Tropics (KIT) in the

[59] Acronym for "Benznidazol and Triazol REsearch group for Nanomedicine and Innovation on Chagas diseasE". http://www.berenice-project.eu/index.php?lang=en

[60] http://www.sabin.org/programs/global-network-neglected-tropical-diseases

Netherlands is working on nanodiagnostics, for more rapid detection of Tuberculosis. They are cooperating with partners from research and industry in the Dutch programme NanoNextNL and with partners from developing countries. Also in the Netherlands, The National Institute for Public Health and Environment (RIVM), at Maastricht University, University Medical Centre Utrecht and the company Enceladus are studying interactions of nanomedicine with the immune system. This is relevant to applications of nanotechnology to tropical diseases.

National activities

In **Brazil**, several projects have been funded by the Department of Science and Technology of the Ministry of Health, in association with the Brazilian National Council for Scientific and Technological Development (CNPq) from 2004 to 2010 on “controlled drug delivery systems” directed to *leishmaniasis* treatment. The Brazilian National Institute of Nanobiostructures and Nanobiomolecular Simulation at Federal University of Ceara (UFC), specialized in the biotechnological applications of crystals (of amino acids, DNA, RNA and proteins) including the engineering of crystals for drug development for neglected diseases. At the Federal University of São Paulo (UNIFESP) the Department of Ocular drugs and Therapies works on nano for therapies for neglected ocular diseases. The recently created Laboratory of Nanomedicine and Nanotoxicology (LNN) at the Physics Department of the University of the State of São Paulo at São Carlos city (UNESP-São Carlos) has as one of its priorities the development of new materials for detection of biological substances and biosensors for diagnostics of several health conditions, including neglected diseases. At the Federal University of Rio de Janeiro (UFRJ) research is ongoing on drug delivery and vaccines that target leishmaniasis through transdermal drug delivery. At USP, priorities in nanomedicine research include Leishmaniasis and Chagas disease.

This low level of research activity calls for political involvement in order to address diseases that impact the lives of mostly disadvantaged populations in LA Look et al (2010) also call attention to the technological deficiency of available and effective therapeutics that prevent or alleviate disease progression.

5.2.1.2 Policy and funding for tropical diseases

Funding for research and product development on tropical diseases is very limited. The WHO[61] and Bill Gates Foundation[62] fund research on tropical and neglected diseases, including parasitosis. Recently, the WHO called upon its member states to invest more in tropical diseases (Holmes, 2015). At global level, the Global Fund invests in projects proposed by countries combating HIV/AIDS, Malaria and Tuberculosis. It is not clear if this includes R&D on new drugs and diagnostics in general, or nanomedicine in particular.[63]

[61] http://www.who.int/neglected_diseases/en/
[62] http://www.gatesfoundation.org/

5.2.1.3 Pharmaceutical and Medical Devices Industry and Investment targeting tropical diseases

As an example of achievements in delivery of nanoscale therapies, Look et al (2010) cite the possibility of nanocarrier-based systems to deliver drugs that are administered in many doses in the course of long periods (such as the treatment of visceral leishmaniasis with antibiotic paromomycin in Bihar state in India by the Institute for One World Health).

Liposomal nanomedicine is available and can in principle be applied to the parasite Leishmaniasis. The drug is 1000x more effective after incorporation in a liposome. According to an interviewee it is still not available on the market for three reasons:

1) the costs of development and testing are too high
2) treatment costs are projected to be US$10-12 instead of US$0.10 per pill
3) the drug would have to be injected in hospital while the existing drug can be administered orally.

The market for Tuberculosis therapies and diagnostics is summarised in box 1. Nanotechnology is not used in most existing products, but offers opportunities for new point-of care diagnostics in the future.

Box 1: market for existing tuberculosis therapies

Currently Tuberculosis is treated with a six-month course of antibiotics (WHO 2014a). Multi-drug resistant tuberculosis (MDR-TB) needs a longer treatment time with second-line drugs that are more expensive and have more side-effects. For the treatment of extensively drug-resistant tuberculosis (XDR-TB) there are fewer options available as second-line drugs are not effective (WHO 2013d).

Sputum smear microscopy, culture of the tuberculosis bacteria, detection of bacterial nucleic acids and clinical symptoms are used to diagnose active TB. For latent TB tuberculin test skin test and interferon gamma release assays are used. It is important to diagnose not only active TB cases but also latent TB cases because 10% of the latent individuals can later develop active TB. If the immune system of a latent TB person is weakened the probability of falling ill with TB will grow (Wang 2013).

Low specificity of clinical diagnosis, unavailability to perform diagnostic methods in laboratories of the developing world and incapability to monitor patient compliance to the 6-9 month therapy are reasons limiting TB diagnosis globally (Wang 2013). In 2011 the percentage of new PTB cases in LA that were bacteriologically confirmed by any laboratory method varied between 53% (Guyana) and 98% (Trinidad and Tobago) (PAHO 2013).

Sputum smear microscopy is the most widely used diagnostic test for TB (WHO 2013d). However, sputum smear microscopy has a poor sensitivity meaning that many people with active TB are not found. Also, people with advanced HIV are often not detected by sputum smear. Low cost and rapid results are the reasons for the wide use of sputum smear microscopy. Sputum cultures have a higher sensitivity, but also higher costs and obtaining results takes around 3-4 weeks. Rapid diagnostic tests have

[63] http://www.theglobalfund.org/en/

been developed, some already in use, for example Xpert MTB/RIF, which is able to detect the TB bacterium reliably within several hours (TB Online 2011).

5.2.2 Good practices and Recommendations targeting Tropical Diseases

What are good practices and recommendations for nanomedicine applications targeting tropical diseases developed in Europe and LA with a view to fostering international cooperation? This includes national and regional examples of actions for up-scaling innovation in these applications.

5.2.2.1 Research on nanomedicine for tropical diseases

Look et al (2010) propose the use in the near future of nanomedicines to tackle tropical infectious diseases in the developing world by promoting more effective immunotherapy to prevent or clear pathogen infection. They describe two approaches in which nanoparticles can be used to create new generations of versatile and potent prophylactics: innate immune stimulators and microbicides for short term protection against pathogen transmission in the event of known potential exposure and vaccination strategies that attempt to elicit immunological memory responses to prevent infection, for long term protection.
With regards to diagnostics, Look et al (2010) emphasize that solutions to be deployed in developing countries need to be clinically accurate and reliable, cheap, quick, and simple to use. Such diagnostic solutions could be deployed in “lab-on-a-chip” and other devices that take a sample of the patient’s blood and detect the presence of specific antibodies and immune cells against the pathogen.
A European Community of Interest member recommends that research in nanotechnology could be targeting parasitosis through different ways. This disease may be prevented through some product to be added to the drinking water that kills parasites cheaply and solutions that work without technological needs on site. An example could be of plastic coated with antiparasitic nanomaterials used for water containers. Nanotechnology may also be used in vaccination against parasitosis. The vaccines should be cheap, have no economic value in order not to be stolen and require no refrigeration. There are very practical problems to develop vaccines addressing poor people in developing countries.

5.2.2.2 Policy and funding for tropical diseases

WHO recommends that all countries should invest in research on tropical diseases and that the identification of research priorities is embedded at the national level where the diseases are endemic. They encourage national governments and international donors to invest in research and supporting mechanisms for sharing information and data and in strengthening research training and institutions. Basic research can be assisted by

Northern institutions, but research on implementing these new and improved tools must be done in the country and the capacity to do so must be built (Holmes, 2015).

5.2.3 Producing technologies and applications in the future

How can solutions, technologies and applications be produced in the future for nanomedicine applications targeting tropical diseases developed in Europe and LA with a view to fostering international cooperation? This includes solutions needed, timeframe for implementation and action steps (at national, EU and LA level) for developing applications in LA.

5.2.3.1 Research on nanomedicine for tropical diseases

In general nanomedicine is not included in current international strategies for combatting tropical diseases. There appears to be a gap between stakeholders interested in tropical diseases and stakeholders interested in nanomedicine.

However, NMP-DeLA community members mentioned the following opportunities for targeting their research to tropical diseases in cooperation with Latin American partners.

- Work at Fiocruz BR on nano-diagnostics and drug delivery could be focused on HIV, Malaria and TB. However, this is expensive to develop and calls for global initiatives.
- The Department of Biology, Chemistry, Pharmacy of the Institute of Chemistry and Biochemistry, at the Freie Universität in Berlin has expertise on drug targeting (dendritic polymers), that could be applied to neglected diseases: leishmaniasis, chagas. This could be achieved through adapting the same nanoparticles they are preparing, by changing the ligands at their surface for instance. They are currently working with groups in Spain and at MIT.
- Paris Lodron University's research on asthma and allergies could be targeted to investigating why Latin American countries such as Brazil and Peru have a higher allergy incidence than other countries. In addition, it could focus on parasitosis, because allergies arise as result of the body's anti-parasite system being activated by mistake. By extension, it could be possible to bring the substantial R&D effort on allergies in industrialised countries to bear on the work being performed in the tropics on parasites.

5.2.3.2 Policy and funding for tropical diseases

There is still a risk of a "nanodivide" regarding the deployment of nanomedicines for the well-being of poor populations around the word. As there was no mention of deploying nanotechnologies for treatment of neglected tropical diseases (NTDs) in WHO's accounts of the NTDs (WHO 2013), this may be an indication that political desire for developing advanced technologies for the treatment of these diseases is still weak.

At the international level, the negotiations on the Sustainable Development Goals with a time horizon until 2030 are converging on a proposed list of 17 Goals supported by 69 UN Member States. The proposed Goal 3. “Ensure healthy lives and promote well-being for all at all ages” includes a tentative point 3.3 “by 2030 end the epidemics of AIDS, tuberculosis, malaria, **and neglected tropical diseases** and combat hepatitis, water-borne diseases, and other communicable diseases”.[64] Even though the way forward to achieving this goal is not specified down to the level of specific technological solutions such as nanotechnology, the goal can function as a benchmark helping to coordinate efforts of the stakeholders including those interested in nanomedicine.

5.2.3.3 Pharmaceutical and Medical Devices Industry and Investment targeting tropical diseases

In general, WHO recommends building on successes through public private partnerships to develop new medicines, vaccines, diagnostics and vector control methods. “Public and private sector incentives must be set up to encourage NTD research and development using appropriate collaborative measures that can allow exchange of expertise and scientific knowledge through:… a variety of measures including corporate responsibility schemes and platforms such as the Uniting to Combat NTD coalition, to encourage innovative incentives.”[65]

NMP-DeLA community members mentioned some opportunities for developing products targeting tropical diseases.

- Current activities at FIOCRUZ, BR on nanoparticle for diagnostics could be focused on three or four tropical diseases, e.g. schistosomia, leishmaniasis, and malaria. This fits with the existing Brazilian programme on treatment and diagnosis of Leishmaniasis.
- An Argentinean start-up, LATINER, is working on nanoparticles for tropical diseases including Chagas disease and possibly also Leishmaniasis. This is a public-private enterprise. Projects are funded by government subsidies until the platform technology is mature and then patented and licenced.
- In Europe, the NANOFACTURING project supports the development of antiviral dengue fever nanopharmaceuticals at the Italian foundation for Cancer Research’s Institute of Molecular Research.[66]

Good examples of developments for diagnostics have been studied by two EU-funded projects: Technology Platform for Point-of-Care Diagnostics for Tropical Diseases (PODITRODI) and Disc-shaped point-of-care platform for infectious disease diagnosis (DiscoGnosis[67]). PODITRODI ended in 2011 and aimed to analyze proteins and DNA-strains of tropical disease pathogens using advanced point-of-care technologies. DiscoGnosis runs until October 2015 and its objective is to develop a platform for detection of malaria and similar pathogenic diseases in a rapid, multiplexed and non-invasive way. According to Smit (2013) the estimated time to market is 6 - 8 years.

[64] http://sustainabledevelopment.un.org/focussdgs.html
[65] http://unitingtocombatntds.org/
[66] http://www.etp-nanomedicine.eu/public/about-nanomedicine/nanomedicine-pilot-lines/nanomedicine-pilot-programmes
[67] http://www.discognosis.eu/

5.3 Cancer

5.3.1 State of the Art

How is NMP deployed (now) in the context of societal challenges in the field of health for applications targeting cancer developed in Europe and LA with a view to fostering international cooperation? This includes existing solutions identified for improving the capacity to develop innovative pharmaceuticals and medical devices targeting cancer in LA, and their stage of development.

5.3.1.1 Research on nanomedicine for cancer

While cancer is not a priority topic in nanomedicine research in LA, the mapping exercise carried out in NMP-DeLA has identified some groups and individuals working on this, per country.

In **Brazil**, the Department of Science and Technology of the Ministry of Health, in association with the CNPq, has, from 2004 to 2010, funded several projects on “controlled drug delivery systems” directed to cancer. Such research targeting cancer has been carried out at the Federal University of Rio de Janeiro (UFRJ). The recently created Laboratory of Nanomedicine and Nanotoxicology (LNN) at the Physics Department of the University of the State of São Paulo at São Carlos city (UNESP-São Carlos) includes research on the toxic effects of nanoparticles and carbon nanotubes on healthy and cancer cells. The Centre for Nanotechnology and Tissue Engineering of USP produces nanostructured photo-activated drugs for skin cancer treatment. It cooperates with the Excellence Centre for the Treatment of Cancer in Belém do Pará, Brazil.

In **Mexico**, the Centro de Investigación y Asistencia en Tecnología y Diseño del Estado de Jalisco (CIATEJ) is working on a chip containing nanoparticles of gold for early detection of cancer. At the Centre for Research and Advanced Studies (CINVESTAV) of the National Polytechnic Institute (IPN), research is ongoing targeting nanomaterials for treating cervical cancer and precancerous cells. In the Mexican Institute of Social Security (IMSS) there is research on new diagnostic methods for cancer and other diseases. In addition, researchers at the Institute for Biotechnology, University of Sonora, are investigating cancer.

In **Argentina**, the Laboratory of Highly Reactive Species at the Instituto de Investigaciones Fisicoquímicas Teóricas y Aplicadas (INIFTA) works on nanomaterials, toxicity and cancer. The faculty of Exact Sciences of the National University of Rio Cuarto works on photo-assisted cancer therapy. Instituto Leloir works on nanomedicine for cancer. The Laboratory’s gene therapy designs and applications are patented. They apply Camelid (Llama) anti-bodies found in LA. They cooperate with INIS Biotec, Instituto Leloir technologies incubator. Through their Argentinean partner company, Immunova, they are in touch with Ablynx, which is in the business of screening Llama antibodies against therapeutic targets, and received US$20 billion investment from Merck. They also cooperate with Argentinean family laboratories.

In **Chile**, the Centre for Advanced Interdisciplinary Research on Materials Science (CIMAT) at the University of Chile works on magnetic nanoparticles for cancer treatment and the Centre for Bioinformatics and Molecular Simulation at University of Talca, in cooperation with the Fraunhofer Institute, works on cancer treatment. The Centre for Integrative Medicine and Innovative Science (CIMIS) at Andrés Bello University and University of Santiago in Chile are cooperating in the Higher Education Quality Improvement Programme (MECESUP) project. This applies modelling to early detection of cancer cells. Other applications are in neuroscience, pain treatment and drug release of antibiotics. They host the best computer facility in Chile.

In **Colombia**, the interdisciplinary network of the Nanoscale Science and Technology Centre (NanoCiTec) works on cancer and nanotechnology. Overall, Colombia´s research groups have a strong focus on nanotechnology applied to cancer research.

5.3.1.2 Pharmaceutical and Medical Device Industry

Several nanoscale drug delivery products are on the market, mainly for cancer. The interest of industry is more in prolonging the patent life of anti-cancer drugs, according to some NMP-DeLA Community of Interest members. In a collaboration between Israel and Brazil, the Nanose diagnostic devices have been developed that can diagnose different cancers in the body.

5.3.1.3 Responsible Research and Innovation aspects

Clinical trials are essential to the process of developing new cancer treatments. In LA participation in clinical trials can be an attractive option for patients as trials provide access to novel and otherwise unattainable medical therapies. Mexico, Brazil and Argentina are the most established in clinical research (Virk, 2009). Such clinical trials in developing countries are a sensitive issue that has been the topic of a report of the European Group on Ethics to the European Commission in 2003.[68] In European funded projects, proposed trials are subject to ethical review before funding is approved.

5.3.2 Producing technologies and applications in the future

How can solutions, technologies and applications be produced in the future for nanomedicine applications targeting cancer developed in Europe and LA with a view to fostering international cooperation? This includes solutions needed, timeframe for implementation and action steps (at national, EU and LA level) for developing applications in LA.

5.3.2.1 Research on nanomedicine for cancer

In most countries cancer is one of the promising application areas of nanomedicine, but not the subject of a separate strategy. The US National Cancer Institute's (NCI) Alliance on Nanotechnology in Cancer[69] has been implementing such a strategy targeting nanotechnology for cancer since 2005, including Centres of Cancer Nanotechnology Excellence, Cancer Nanotechnology Platform Partnerships, Cancer Nanotechnology Training Centres, Pathway to Independence Awards in Cancer Nanotechnology Research and Nanotechnology Characterization Laboratory.

The ETP-Nanomedicine White Paper "Nanomedicine 2020" includes cancer as one of its target diseases, but does not include a separate chapter dedicated to cancer.[70]

5.3.2.2 Policy and funding for cancer

While the EU does not have a specific programme targeting nanomedicine for cancer, the current workprogramme 2014-2015 in Horizon 2020 includes one call targeting nanomedicine therapy for cancer. It foresees an investment of 6-9 million euros per project.[71]

Countries across the globe are drafting biosimilar regulations to reduce the cost of biological therapeutics testing and improve patient access to low-cost drugs for cancer and other diseases. While the EU has allowed biosimilars for several years, the first biosimilar drug is only entering the US market in 2015, surrounded by controversy.[72]

6 Module: Solutions for water

General applications of nanotechnologies for water fall under remediation of polluted water, potabilisation of water, desalination and nanodevices (sensors for water quality monitoring).

6.1 State of the Art

In this chapter we want to give an overview how NMP is currently deployed in the context of societal challenges in the field of water. This question will be addressed for the production of clean water and for monitoring water quality in Europe and LA, with a view to fostering international cooperation. This includes existing

[68] http://ec.europa.eu/archives/bepa/european-group-ethics/docs/avis17_en.pdf
[69] http://nano.cancer.gov/
[70] www.etp-nanomedicine.eu
[71] https://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/2501-nmp-11-2015.html
[72] http://www.nature.com/news/first-biosimilar-drug-set-to-enter-us-market-1.16709

solutions that have been identified for improving the capacity to develop innovative water technologies in LA and their stage of development.

6.1.1 Research targeting NMP for water

The results of the NMP-DeLA bibliometric study (Invernizzi et al 2015) show that 435 articles from Latin American authors focus on nanotechnology for water applications. Of these, the area of contaminated water remediation is addressed in 257 published articles. The issue of water potabilization is addressed in 227 articles and water desalination has been the subject of 3 articles. Several articles address multiple application areas.

Researchers in 13 Latin American and Caribbean countries have published on nanotechnology for water applications since 2000. Per country, Brazil is most productive with 360 articles, followed by Mexico (136), Argentina (90) and Chile (56). The analysis presented in Invernizzi, et al (2015) offers an overview of co-publication patterns, scientific authors and affiliated organizations in nanotechnology research with a focus on water A detailed qualitative analysis and collection of contact data was conducted for those countries that were identified as remarkably productive by the preceding bibliometric study. A summary of results follows with the remark that due to the different amount and quality of information available it is difficult to make a comparison between countries. In the following sections, we present country-specific data on the findings of the bibliometric mapping, additional information can be found in paper by Invernizzi et al (2015).

Brazil

According to Invernizzi et al (2015) 15 Brazilian research groups target nanotechnology for desalination, potabilization, environmental remediation and sensors/monitoring. Three additional groups cover a broader scope including water applications.

The following laboratories are active in nanotechnology for water: Desalinization Reference Laboratory (LABDES) at the Department of Chemical Engineering, Federal University of Campina Grande[73]; Advanced Water Treatment and Re-use Laboratory (LATAR) at the Department of Water and Sanitation, São Carlos Engineering School[74]; Mineral and Environmental Technology Laboratory at the Engineering School of the Federal University of Rio Grande do Sul (UFRGS)[75].

Koiti Araki's laboratory at USP is working on nanocomposites for removal of soluble pollutants and treatment of water. At the Laboratory on Mineral and Environmental technologies/UFRGS they study nanobubbles: generation, properties and potential applications on water/wastewater treatment in cooperation with PETROBRAS and another company.[76]

Mexico

[73] http://www.labdes.ufcg.edu.br
[74] http://www1.eesc.usp.br/shs/index.php/area-1/19-latar
[75] http://www.ufrgs.br/ltm

Research on nanotechnology for water is spread over a wide range of universities and research centres, with only one or a few researchers in each group. Invernizzi et al (2015) have identified groups in 27 research centres or institutes in ten institutions across the country.

The National Water Commission (CONAGUA) and the National Council of Science and Technology (CONACYT) Sectoral Fund have each funded two projects on nanotechnology for water.

David Smith, in his presentation at the NMP-DeLA workshop in Mexico reported that CONACYT has in the past hosted a network on water. Maria Teresa Alarcon Herrera, in the same workshop reported that the Center for Research on Advanced Materials (CIMAV) in Durango is working on nanomaterials and drinking water treatment technologies[77].

Argentina

Nine research groups are working on nanotechnology for remediation of contaminated water: Centro de Ingeniería en Medio Ambiente at the Buenos Aires Institute of Technology (ITBA)[78], Programa de Química Combinatoria de Materiales Avanzados and Laboratory of the Program of Nano and Mesomaterials at the National University in Rio Cuarto; the Institute of Research in Catalysis and Petrochemistry (INCAPE)[79] at the National University of Litoral in Santa Fé; Laboratory of Species Highly Reactive ((LEAR) at the Research Institute of Theoretical and Applied Physical Chemistry (INIFTA)[80]; the Atomic Centre of Bariloche of the National Commission of Nuclear Energy (CAB-CNEA) [81]; Fisioquímica Area de Catálisis ambiental. Materiales nanoestruturados INCAPE; the Group Technology of Water Remediation at CNEA/University of San Martín; the Group Optical Laser of Materials and Eletromagnetic Applications (GLOmAe) at the University of Buenos Aires (UBA)[82]; and the National Agricultural Technology Institute (INTA)[83].

At the National University of La Plata, Daniel Martire is working on nanomaterials for the adsorption and photodegradation of contaminants and Eduardo Miró at the National University of Litoral focuses on Nanomaterials for Catalytic Processes applied to water treatment.[84]

Chile

Three research projects on nano for water were carried out at the Centre for the Study of Nanoscience and Nanotechnology (CEDENNA) and the Department of Chemical Engineering at Universidad de Concepción. (for more information see Invernizzi et al 2015). Relevant research at CEDENNA includes synthetic nanoparticles for eliminating arsenic in the North of Chile, and for perchlorate remediation in soil, as well as for removing heavy metals from water and the synthesis of new materials for water decontamination. Bernabé Ri-

[76] See their presentations during the NMP-deLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu
[77] See their presentations during NMP-deLA workshops, www.nmp-dela.eu
[78] www.itba.edu.ar/cima
[79] WWW.fiq.unl.edu.ar/incape/
[80] www.lear.quimica.unlp.edu.ar
[81] http://física.cab.cnea.gov.ar/resonancias/
[82] http://laboratorios.fi.uba.ar/glomae/
[83] www.inta.gov.ar
[84] See his presentation during the NMP-deLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu

vas Quiroz' group at Univ. de Concepcion is working on polymer-clay nanocomposites for the removal of oxyanions. [85]

Colombia

Two research groups at two separate universities are working on the environmental remediation of water: the Javeriana University and the Medellín University. The Colombian nanotechnology network RedNANOColombia has developed a roadmap for nanotechnology including nanomaterials and sensors for water treatment and energy production in the same context. Challenges include green synthesis and processing, scaling-up, lifecycle analysis for the nanomaterials used, and a holistic approach[86].

Uruguay

Only the Technology Cluster Chemistry Department at the University of the Republic is working on nanotechnology for water.

Europe

The Water Supply and Sanitation Platform (WSSTP) coordinates research on water[87]. The EU funded Research and Innovation Staff Exchange (RISE) project NANOREMOVAS aims to develop solutions for removing Arsenic from groundwater in Argentina.[88]

NMP-DeLA Community of Interest members are already involved in EU-Latin American cooperation in nanotechnology for water, including the following examples:

- The NHL University of Applied Science in the Netherlands is among others cooperating with three large universities in Brazil: Federal University of Viçosa, USP, and Federal University of Ceará on physically driven systems, combining electrohydrodynamics with nanotechnology for evaporation and distillation. Together with USP and the company Arkadis they are engaged in a project for nitrate removal in ground water that started in October/November 2014.
- The KWR Water Cycle Research Institute in the Netherlands has developed nanomodified membranes for water purification, which is still at the lab scale and an early stage of development. It has used adsorption on nano-engineered membranes (e.g. ceramic, self-cleaning, catalytic, mixed matrix etc.) and has tested desalination membranes produced by HTO on real Dutch sea water with relatively low salt contents.
- The University of Guanajuato in Mexico is working on nanomaterials for cleaning waste waters.
- The University of Concepcion in Chile has been working for 30 years on the decontamination of water, more specifically on the removal of inorganic contaminants by using polymers, and during the few past years through nanocomposites.

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[85] See his presentation during the NMP-deLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu

[86] www.rednanocolombia.org see also presentation by Edgar Gonzalez during NMP-DeLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu

[87] http://wsstp.eu/

- The environmental nanotechnology group at the University of Bath in the United Kingdom is working on metallic membranes, where pore sizes can be modified hydrothermally and branched pores can be created through application of different voltages They are already cooperating in LA with UNICAMP, USP, UNAL (Colombia), UNAM (Mexico) and with South Africa (Stellenbosch).

6.1.2 Education in water applications

The NHL University of Applied Science in the Netherlands is cooperating in student exchanges with the Federal University of Viçosa and the Federal University of Fortaleza in Brazil. The topic is water technology, physically driven systems, combining electrohydrodynamics with nanotechnology.

6.1.3 Water Sector Industry and Investment

In Brazil, six companies are applying nanotechnology to water treatment, including three spin-offs from university research groups: Ocean Par [89]; Perenne Equipamentos e Sistemas de Água, Ponto Quântico Nanodispositivos, Contech Produtos Biodegradáveis Ltda[90], POLICLAY, Nanotech Indústria e Comércio Ltda[91], and H2Life[92].

According to an NMP-DeLA Community of Interest member, two Dutch engineering companies are interested in nanotechnology for water and have activities in Brazil: Arcadis[93] and Paques[94]. Arcadis applies electrohydrodynamics including nanoscience in the production of encapsulation and nanoparticles and nitrate removal from water. Paques incorporates nanoscience in innovative methods for the production of bioplastics and is active in removal of ammonia from waste water without nanotechnology.

A small Dutch company, Magneto Special Anodes[95], is interested in entering the Brazilian market. It produces electrodes which can be used for sea water electrolysis. The Brazilian sanitation company Segolin is also interested in nanotechnology.

In Guanajuato, **Mexico**, local researchers have compared nano-enabled water treatment systems with commercial systems in cooperation with Rice University, USA, and water officials from the State of Guanajuato. The test lasted 4 months and is affordable at pilot scale (US$0.16/l). It now needs to further development to manufacturing scale. In India, professor Pradeep[96] has used nanotechnology to remove arsenic and

[88] http://cordis.europa.eu/project/rcn/194273_en.html
[89] http://www.aquamarewater.com/
[90] http://www.contechbrasil.com
[91] http://www.nutec.ce.gov.br/index.php/nutec-partec/empresas-incubadas/residentes/43491
[92] http://h2life.com.br/index.php?p=noticias&a=sistema-h2life
[93] http://www.arcadis.nl/index.aspx
[94] http://en.paques.nl/
[95] www.magneto.nl
[96] Department of Chemistry, Indian Institute of Technology Madras, http://www.dstuns.iitm.ac.in/t-pradeep.php

is working on adapting this to fluorides. However, it is more expensive at US$0.78/l.[97] Zayago, Foladori and Arteaga (2012) have identified 8 companies applying nanotechnology in the water sector in Mexico.

According to NMP-DeLA Community of Interest members, several **French** companies are also interested in nanotechnology for water in cooperation with LA, including Veolia and Suez-Environnement. Other French and Dutch companies are active in nanotechnology for water applications, but it is not clear if they are interested in cooperating with LA.

According to the OECD (2011), General Electric[98], Siemens[99] and Dow Corning[100] are also interested in nanotechnology for water. However, Dow Corning does not include nanotechnology in its current R&D strategy according to an interviewed expert. A distinction should be made between nanotechnology and nanofiltration, since the latter does not use nanotechnology.

6.1.4 Water-related Ethical, Legal and Societal Aspects

A study on the expectations for nano-applications in water quality monitoring and food in the Netherlands demonstrates that nanotechnology for water is considered a sustainable solution for water purification (te Kulve et al, 2013).

6.1.5 Policy and funding for NMP for Water

At an international level, several institutions are working on the global water issue, but innovation in general, and nanotechnology in particular, are not among the priorities in their policy or funding strategies.

According to Invernizzi (et al, 2015) the **Brazilian** government has never explicitly targeted water in its national nanotechnology strategies since 2004, but water applications are covered in the priority “environment” in the current 2012-2015 strategy, in general, and in the national nanotechnology laboratory system SisNANO in particular. Under several calls for proposals by CNPq, seven projects targeting nanotechnology for water applications have been funded, mainly targeting waterway decontamination. Much of the funded research in nanomaterials, sensors, and membranes, has multiple uses and can be applied to the decontamination of water and the production of potable water.

[97] See for more information presentation of Maria Teresa Alarcon, CIMAV during the NMP-DeLA workshop in Curitiba and Invernizzi, Foladori and Lindorfer, 2015, www.nmp-dela.eu
[98] http://www.gewater.com/product-directory.html
[99] http://www.energy.siemens.com/hq/pool/hq/industries-utilities/oil-gas/water-solutions/pdf/fact-sheet-water-solutions.pdf
[100] http://www.dowwaterandprocess.com/en/Products/Reverse_Osmosis_and_Nanofiltration

In Brazil, MCTI is exploring how nanotechnology can contribute to the main goals of the MCTI coordination on water management. In NanoREG they foresee a cooperation programme on nanotechnology and water.[101]

6.2 Water-related Good practices and Recommendations

What are good practices and recommendations? This question will be addressed in this section for the production of clean water and monitoring water quality developed in Europe and LA with a view to fostering international cooperation. This includes national and regional examples of actions for up-scaling innovation in these technologies.

6.2.1 Research targeting NMP for Water

NMP-DeLA Community of Interest members recommended:

- Building a network of experts on water technology and nano-specialists by organizing conferences or seminars focusing on nanotechnologies applied to water. Latin American researchers could be linked to European networks, starting with Spain, Portugal (and the USA).
- Mexico, Chile and Argentina have similar problems related to water, especially related to arsenic contamination, which may be addressed through nanotechnologies (e.g. for detecting the presence of arsenic and immobilising it on membranes). In Chile the main challenges are understanding the state of the art, creating networks amongst universities and research centres and securing funding for applied investigations. Partners in projects should include mining companies and local authorities with contaminated water problems. Social organizations should also be engaged in order to raise people´s awareness of water contamination.
- Applications of nanotechnology in water treatment should be developed through safety by design. Nanoparticles for water treatment should be immobilised to ensure they do not escape into the environment.
- End users should be involved from the beginning to make sure that the solutions are useful to them.
- Bringing African, Latin American and European experts together by means of a conference on water treatment by solar energy, in order to solve their common problems.
- Engaging in the IWA working group on nanotechnology, which is doing work in Africa including organizing conferences.
- There are opportunities for applying nanotechnology, especially membranes, in the remediation of mining water effluents. The main problem is that there are few nanotechnologies for water applications at an industrial scale, most are at the lab-scale. These are still expensive and have a long time to market. There are further issues with safely disposing of waste liquids containing solvents used in some systems to clean the nanomaterial.

[101] C.f. presentation Anna Tempesta during NMP-DeLA workshop in Curitiba, 28-29 June 2015, www.nmp-dela.eu

- Opportunities in cooperation between Europe and LA are in upscaling lab scale membranes and materials to immobilise or degrade toxic chemicals and microbes.

6.2.2 Policy and funding for NMP for Water

Experts and Stakeholders involved in an OECD study on nanotechnology for water recommended:

i. "Governmental and intergovernmental bodies supporting collaborative research and development should consider ensuring that the potential of nanotechnology as a solution to global challenges such as water is reflected in their funding allocations.
ii. Stakeholders – government, non-government international bodies and industry – should support and engage with work on addressing fiscal, economic and social issues at national and international levels for different types of source waters, in conjunction with national and international initiatives on nanotechnology and water.
iii. Countries should consider coming together in an international event on nanotechnology and water bringing together participants from the water industry, the nanotechnology industries including materials, and sensors, the science and public health communities, OECD governments and the OECD enhanced engagements countries to discuss the key issues raised in this paper, from needs to technological solutions; to exchange good practice examples in the use of nanotechnology and other technologies for the enhancement of water systems; and to identify steps to be taken by national and international governmental bodies to optimise the use of nanotechnology in the water sector."[102] (OECD, 2011: p 42-43)

According to a NMP-DeLA Community of Interest member, water purification should be implemented in LA by overcoming difficulties in dealing with public markets (corruption, delays), as the administration of the water sector is dominated by municipalities.

6.2.3 Water Sector Industry and Investment

Interviewed NMP-DeLA Community of Interest members recommended:

- Developing affordable and sustainable sea water desalination solutions for rural households in remote coastal areas: such stations, with a capacity of approx. 1 cubic metre/day should be driven by renewable energies, such as solar-thermal, geothermal and wind. For these to be successfully implemented, overhead and maintenance costs (in money, not in working hours) should be kept to a minimum.
- The massive generation of fresh water for agricultural irrigation purposes and cities: New desalination approaches must envisage the use of geothermal energy where available. Such desalination solutions

[102] These countries include Mexico, Chile and Brazil as well as the EU and EU member states.

clearly call for modern, nano-enhanced material solutions, which need to be designed in terms of cost, mechanical strength, chemical and ultra-violet radiation resistance and environmental friendliness.

- Cooling perishable food, by contributing to the development of solar-thermal driven cooling solutions for food preservation and ice production in remote areas: The idea is to use solar energy to produce ice that can be used for cooling food. For this field, approaches with nano-enhanced materials should focus on efficient, but environmentally friendly heat insulation materials and large surface concentrations for water absorption / desorption in the production of ice. NMP applications should focus on materials (e.g. heat insulators), as well as nano approaches for the creation of very large spatially confined water surface areas for enhanced water evaporation.
- The production of advanced water treatment systems through the design and optimization of hybrid systems that reduce fouling and increase process efficiency and longevity, by scaling up manufacturing of materials and processes.
- Water treatment by photocatalysis, that can be used for aqueous effluents with low pollutant concentration (pesticide, drugs, others organic pollutants), and take due consideration of nanosafety issues if used as drinking water (due to potential release of nanoparticles).
- Cheap and fast point-of- use sensors/lab-on-a-chip for field-based measurements of water purity: A good practice is the Canary project (security, disaster relief, remote areas) in the USA.[103]
- Improving waste water collection and consequent treatment: Treatment should involve new technology based solutions, including nanotechnology, e.g. desalination. In Brazil: 30% of waste water is collected, and only 30% of this is treated. Discussions on this topic are ongoing, however there are budgets available. In Costa Rica, an expert foresees that there is interest in using nanomembranes for filtration and nanoparticles for labelling pollutants of water.
- In Chile, a foreseen market niche has been identified for the use of nanocomposite resins in the decontamination and reuse of dirty water.
- In Chile, water distribution companies and companies in general that contaminate water because of their activities should be engaged in projects deploying nanotechnology for water purification. This includes mining companies.

6.2.4 Water-related Ethical, Legal and Societal Aspects

According to Alejandra Martín Dominguez, in **Mexico**, a bottleneck hampering the introduction of nanofiltration and photocatalysis with TiO2 nanoparticles is the price, especially in regions where water consumption is not charged or if charged, bills are not paid. In addition, polluting companies would rather pay fines than invest in water purification plants.

[103] See: https://www.ted.com/talks/sonaar_luthra_meet_the_water_canary , http://www2.epa.gov/homeland-security-research/models-tools-and-applications-homeland-security-research

Interviewed NMP-DeLA Community of Interest members recommended:

- To study potential users of the nano-enabled technology and the institutional, legal and operational context: who are the actors, what are the current regulations, how easy or difficult it is to introduce nanosensors/ nanotechnology in the production and distribution chain. This is to identify where nanotechnology can be applied in a sensible way.
- Demanding articulation of nanotechnology solutions for water treatment in LA, by comparing these with other technological or non-technological solutions to current conflicts between water pollution and use. Solutions need to be checked for simplicity, maintenance difficulties and costs.
- Mexico and Chile are discussing the same topics, but not the same problems related to water. It is important to discuss among Latin American countries common solutions and characteristics, technical and economic aspects.
- Nanotechnology for water could contribute to real improvement in the quality of living for Chilean people, as it could bring a solution to the problem of consumption of water carrying traces of arsenic, which has not been possible to remove effectively using existing technologies.

6.3 Producing technologies and applications in the future

How can solutions, technologies and applications be used in the future for the production of clean water and monitoring water quality developed in Europe and LA with a view to fostering international cooperation? This includes solutions needed, timeframe for implementation and action steps (at national, EU and LA level) for developing the technologies in LA.

6.3.1 Research targeting NMP for Water

In **Europe**, the European Innovation Partnership Water is managed top-down by the European Commission and aims to foster innovative solutions for European and global water problems.[104]

NMP-DeLA Community of Interest members see the following opportunities for fostering research on nanotechnology for water applications in LA and in EU-LA cooperation:

- In general nanotechnology for water and wastewater treatment is at a laboratory scale and not a widespread technology. It is promising and breakthroughs are foreseen in the coming years. However, it is important to keep in mind the environmental fate, stability and toxicity of any nanomaterials. The aim is to scale up any promising developments at the lab scale in universities of nanotechnology for water purification to pilot or full scale in the long term.

[104] http://www.eip-water.eu/

- There are also opportunities in point of use technologies in developing countries, for example below the sinks in houses or as a stopper on water bottles with nanotubes. Palladium catalysts can be used for the catalytic reduction of nitrates, relevant for small communities of 10 families to purify groundwater. In photocatalytic systems, a major issue is how to get sufficient light to the photocatalyst for it to be active and degrade contaminants. This needs to consider that water also absorbs light, and such systems may need to purify 10,000 m^3 per hour.

Interviewed Community of Interest members' own research:

- In process technologies: use nanotechnology to improve the efficiency of water process technologies through electrohydrolization, spray-dry nanoproduction and coating to see if the coagulation efficiency can be increased in such processes for organic removal, flocculation, to improve distillation and evaporation, thermal desalination.
- Sea water desalination, using water mist that is composed of micron and sub-micron-size droplets considering distillation rates, and scaling up available prototypes.
- Cleaning up pollution by micro- and nano-particles which originate from weather exposed plastic debris at the countries on the Pacific coast.
- The production of novel materials for extreme conditions in water processing by combatting of fouling and biofouling.
- CIMAV in Mexico is applying the mineral Lepidocrocite nano-IronOxide to remove arsenic in ground water at point of use.
- The Spanish technology centre CTM participates in the Catalan Water Partnership which is developing solutions for global water challenges in cooperation with partners in other world regions. It is also partnering in the EU-funded project NanoREM, on nanoremediation, technology development and safety, nitrate, nitrogen and phosphate removal; and in the DEMOWARE project for water potabilization.
- USP in Brazil can produce silver and 2 other nanoparticles at pilot scale. They can produce 10 litres of magnetite in solution per day, and are looking for partners for further development.

6.3.2 Policy and funding in NMP for Water

According to a Community of Interest member, the **Brazilian** government has planned major investments in water infrastructure development. This offers opportunities for trying out new concepts that are difficult to implement in the European water sector including NMPs, provided that good technical concepts can be developed.

Even though it does not cover nanotechnology for water, the City Blueprint tool developed by KWR Water Cycle Institute in the Netherlands offers a quick scan for cities to analyse their water problems in order to identify solutions[105]. One scan has been made for Belém in Brazil. The tool is included in the portfolio of the

[105] http://www.watershare.eu/tool/city-blueprint/start/

European Innovation Platform Water[106].The City Blueprint will be developed further in the Horizon2020 project BlueSCities.[107] This is an example of water related cooperation and connections between Europe and LA.

In **Mexico**, the Secretariat for Economic Development and Tourism of the Government of the State of Tabasco[108] is interested in exploring nanotechnology-based solutions for water pollution that are affecting its main economic areas of oil and food production.

6.3.3 Water Sector Industry and Investment

According to a survey respondent, technologies which are intended to increase the access to clean water represent a relevant market opportunity. Such technologies should be cost-effective, have a relatively simple mode of operation, and a sufficient lifetime without requiring replacement parts. The total lifetime cost is an important factor in encouraging adoption. This respondent believes that the commercial value of nanotechnologies for environmental remediation – which includes other applications beyond pollution removal is in the low tens of millions (USD). The fraction of nano-enabled products has been increasing during recent years, and this trend is reasonable and likely to continue in the future.

Nanofutures has identified different energy and water innovation research needs[109]. There are opportunities for cross fertilization between sectors.

According to the NMP-DeLA Community of Interest members, several companies have the interest and capacity to develop nanotechnology for water applications. These include:

- Instrument manufacturing companies that could apply nanosensors and lab-on-a-chip to measure fluid dynamics in platform technologies for applications in food, water and health. The barriers to overcome are differences in the organization of these sectors and regulations.
- Nanotecnia in El Salvador applies evaporative cooling technique, employing thermal solar energy and locally available and ecologically non-hazardous materials for water absorption (e.g. ground volcanic minerals, salts) and heat insulators (decomposable organics/bio-organics)[110]
- The incubator of the Universidad Francisco Gavidia in El Salvador is establishing start-ups that could specialise in the local production of commercial water desalination and solar cooling systems.
- Two Dutch spin-offs from the Water Research Centre WETSUS are active in nano for water. High Voltage Water BV[111] is developing electrospray technology for process technologies in desalination and

[106] http://www.eip-water.eu/
[107] http://www.eip-water.eu/sites/default/files/HORIZON_2020_BlueSCities.pdf
[108] http://sdet.tabasco.gob.mx/
[109] www.nanofutures.eu
[110] www.nanotecnia.net
[111] http://www.highvoltagewater.com/

membrane production and Metal Membranes[112] manufactures nanopores in membranes for filtration.

6.3.4 Water-related Ethical, Legal and Societal Aspects

According to a survey respondent, environmental pollution from human activities is a global problem. One of the most challenging areas is providing safe drinking water, especially to smaller towns and rural areas. Photocatalytic nanomaterials are most widely used for environmental, cleaning, and aesthetic applications and can reduce pollutants and minimize the need for chemical cleaning agents, resulting in benefits on the health of the general public and thus on the quality of life.

6.4 Case study: Nanotechnology based solutions for conflicts over Water Pollution through Mining

In the discussions and interviews with NMP-DeLA Community of Interest members, a proposal has come up for projects introducing nanotechnology-based solutions for remediating water polluted by mining activities. This frequently gives rise to controversy in several Latin American countries. This idea fits within the scope of the NMP-DeLA roadmap, but is demand-driven from societal perspective rather than a technology push as are most other developments presented in this roadmap. Therefore it is set aside as a case study.

Even though the legal, societal and economic context varies across countries, the exploration of the context surrounding controversies in the period 1993-2002 over plans for the extension of the Yanacoche gold mine in Peru in the Master thesis of Marco Arana (2002) illustrates the issues at stake. He distinguishes two disputes: the first conflict is over the acquisition of land owned by local subsistence farmers, and the second over use and pollution of water resources. After empowerment and mediation, the farmers were happy to accept what they considered a fair price for their property.

The conflict over water remained unresolved during the ten years of his study. There are two sides to this issue: on the one hand, the mining company requires vast amounts of water for its operations, on the other, the mine is located upstream of several rivers, and downstream agricultural users and in, some cases even city-dwellers, complained about pollution of their drinking water and the water needed for irrigation and cattle. This is especially problematic for farmers because they take untreated water directly from the river for irrigation, cattle drinking and their own drinking water, while working in the fields. More recently, the Huffington

[112] http://www.metalmembranes.com/

Post published a critical analysis of the conflicts over the Yanacoche gold mine, focusing in particular on the role of investments by the World Bank and International Finance Corporation (Huffington Post, 2015).

Similar to this Peruvian case, in Chile, a tremendous volume of contaminated water results from the mining industry. It must be treated, but that would need a completely new technology, for the volume to treat is excessively large, according to a Chilean nanotechnology expert interviewed for this roadmap.

Overall in LA, industrial use of freshwater is not that high. It was about 10% in 2011, including mainly mining, oil and gas, pulp and paper and energy, while agricultural use amounted to about 70%, leaving the rest to households (Frost and Sullivan, 2012). However, the national and regional differences are great. For example, in 2006 only 4% of the water withdrawals in Chile was used by municipalities and 83% by agricultural users. 40% of the industrial use (13% of the total) was by the mining industry (FAO Aquastat b). In Northern regions of Chile, pollution from mining effluent is a problem. Very often these untreated discharges go directly into river basins, lakes and irrigation channels (Perez and Cirelli, 2010).

After a wide consultation with 250 stakeholders, WEF (2013) suggests six building blocks for progress towards a solution, including progressive capacity-building and knowledge-sharing, **a shared understanding of the benefits and costs of mineral development, and collaborative processes for stakeholder engagement**, transparent processes and arrangements, thorough compliance monitoring and enforcement of commitments, and early and comprehensive dispute management. The two highlighted steps are already implemented and focus on designing a multistakeholder approach to develop a better understanding of different groups' needs, expectations and priorities. Good practice examples include the local development council created by Alcoa in Brazil. WEF already established a multistakeholder dialogue in Chile with the International Council on Mining and Metals (ICMM) in 2011. It is using the six building blocks to guide the development of practical actions. A dialogue in Peru was to be initiated at the World Economic Forum on LA in April 2013.

In Chile (the third copper producer worldwide), the national copper company CODELCO and BHP Billiton established a public-private collaboration in 2009, aiming to support 250 world-class local suppliers[113] to develop innovative solutions for local mining-related issues including shortages of water, by 2020. This partnership includes universities and technology centres (BHP, 2011, WEF, 2013).

Similar to both, participants in the NMP-DeLA summerschool on nanotechnology for water and energy in Monterrey considered it important to engage with more stakeholders than nanoscientists, water technology producers and local population. Maintenance and power needs of the systems and the local capacity for this must also be taken into account. **Participants see possibilities for the scientific community to take an initiative for a platform to address these issues.**

An example of a good practice collaborative solution is the public-private partnership to address water shortages and deliver wastewater solutions and potable water to local communities in the Cerro Verde Copper mine in Peru, operated by Freeport-McMoRan. The mine developed a potable water treatment plant after

[113] Defined as selling over 30% abroad and having standards equal to the industry leader.

engagement with local, regional and national stakeholders (ICMM, 2015, p 54). Whether new technologies including nanotechnology were considered has not been discussed.

In Colombia, the national nanotechnology network RedNanoColombia is targeting its research on monitoring and remediation of mercury contamination. A main contributor to this problem is the (artisanal) mining sector. Of relevance is the NANOSENS project which is developing various diagnostic tools, for example to detect mercury (and arsenic) through a network of interconnected sensors (lab in a mobile phone). In the longer term they also aim at nano-remediation. Another aim of the project is green synthesis using precursors from natural sources for mining metal and plant proteins[114] (Gonzalez et al, 2015).

In the long term, up to 2050, the World Economic Forum Mining and Metals Industry Partnership considers seven drivers for change, including a growing concern for the environment and the protection and sustainable management of water. This implies that operations must adhere to stricter environmental standards for lower water consumption and improved waste management, and that environmental performance will be a more significant component in securing and maintaining a project's license to operate. WEF expects limited access to resources including water and higher costs after the introduction of "true cost internalization" in the late 2020s, leading to cooperation between companies, local governments and communities in developing mutually beneficial adaptation strategies and operating standards. Operations in areas where more rain is predicted are expected to invest in more robust storm-water control systems to minimize mixing clean- and dirty-water sources. More stringent requirements will exist for water reuse within operations and post-use treatment (WEF, 2014). These foreseen stricter regulations could offer opportunities for innovation including by nanotechnology in the long term (after 2020). However, with the exception of CODELCO and BHP Billiton, innovative technical solutions for environmental issues are rarely considered explicitly by the current stakeholders. It may be worthwhile to establish contacts and disseminate information about the innovative opportunities offered by nanotechnology along two lines: desalination and remediation. Desalination of sea water to overcome the shortage of freshwater required for mining as well as other local uses is currently a big issue in Chile and Peru, where the government is investing in desalination plants. Nanomaterials including graphene offer opportunities for improved and more efficient membranes in the long term according to the NMP-DeLA specific roadmap on nanotechnology for water.

Remediation of effluents containing toxic liquid waste from mining offers opportunities for nanotechnology (Coetser et al, 2007). According to the NMP-DeLA specific roadmap on nanotechnology for water: *"Today most applications of nanotechnology in mine water remediation have essentially followed the general application of nanomaterials in wastewater treatment and purification. Most research in this area, especially relating to mine water issues, has been performed in laboratory scale context. Large scale implementation of nanotechnology by the mining industry is expected to still take a few decades (Hu and Apblett 2014). As the mining water contain potentially valuable minerals the use of magnetic nanoparticles combined with recovery*

[114] C.f. Edgar Gonzalez, Pontifica Universidad Javeriana, Colombia: the problem of mercury contamination in Colombia, challenges from nanotechnology for measurement and remediation, presentation during NMP-DeLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu

and regeneration is especially appealing. Magnetic nanoparticles for recovery of, e.g. gold from water solutions have been demonstrated in laboratory scale (Forsman et al 2014)."

7 Module: Solutions for Energy

Nanotechnology is being applied in many fields of energy conversion and storage including: solar energy, electrochemical energy storage, hydrogen energy, fossil fuels, and biomass (biofuels). For those five technologies, the subcategories lithium ion batteries, polymer electrolyte membrane fuel cells, solid hydrogen storage are the topics most frequently identified in specialized literature, followed by dye sensitized solar cells, quantum dot solar cells and photocatalytic and photoelectrochemical hydrogen production and supercapacitors whereas other subcategories have four or less occurrences. Other important nanostructured materials are lithium (Li) composites, due to their importance in Li-ion batteries and titanium dioxide (TiO_2), due to its importance in dye sensitized solar cells, quantum dot solar cells and photocatalytic and photoelectrochemical hydrogen production. More specificities on applications of nanotechnology in energy and related to LA can be found in the specific roadmap on nanotechnologies for energy developed by the NMP-DeLA project.

7.1 State of the Art

How is NMP deployed (now) in the context of societal challenges in the field of energy? This question will be addressed for production of NMP-based sustainable energy technologies developed in Europe and LA with a view to fostering international cooperation. This includes existing solutions identified for improving the capacity to develop innovative energy technologies in LA, and their stage of development.

7.1.1 Research targeting NMP for energy

Invernizzi et al (2015) have identified 816 articles on nanotechnology for energy by Latin American authors in the period 2003-2012 in the Web of Science. Details on the distribution per country can be found in that report. A search in a combined Scopus-Web of Science database of peer reviewed literature in 2003-2012 identified 870 publications on nanotechnology for energy with at least one Latin American and one European as co-authors. The most frequently involved Latin American countries are Brazil, Mexico and Argentina and the most frequently involved European countries are Spain, Germany and France. The most active institutions are The Spanish National Research Council (CSIC) and the University of Barcelona in Spain; Cumhuriyet University in Turkey; University of Sao Paulo (USP) and University of Sao Carlos in Brazil; and Universidad Nacional Autonoma de México (UNAM) in Mexico.
While the USP (Brazil) and the UNAM (México) are clearly the most highly ranked in both the Web of Science and combined Scopus-Web of Science studies, other institutions are following. This highlights the importance of Mexico and Brazil in the Latin-American context and the comparably higher ranked Argentinian institution Universidad de Buenos Aires, the Colombian institution Universidad de Antioquia and the Chilean institution Universidad de Chile in the collaboration with Europe.

Brazil

In the period 2010-2013, eight energy related projects have been funded under nanotechnology related calls by CNPq, and 64 nanotechnology related projects under the Energy Sector Fund. FINEP has funded one project on nanoenergy.

37 Brazilian research groups are working on nanotechnology for energy, including ten that cover more than one kind of energy. In thirteen research groups, energy is the main topic. Eighteen groups cover solar energy, nine fuel cells, eight biofuels, five fossil fuels, and seven other topics. Five National Institutes of Science and Technology (INCTs) are spread out across the country. Created in 2009, these Institutes focus mostly on nanotechnology for photovoltaic devices and fuel cells. The Nanotechnology and Solar Energy Laboratory of the Chemistry Institute at the Campinas State University (Unicamp) and the Nano-network at the North-East Centre for Strategic Technologies (NANO-CETENE) are particularly important for nanotechnology for the development of solar cells. For more information see Invernizzi et al (2015).

According to an interviewed expert, UNESP in Brazil is working on molecular and nanomaterials for energy conversion, energy storage and sensor devices, applied in solar cells in many international cooperation projects in the past.

The Federal University of Parana (UFPR) is working on basic organic solar cells, together with the companies Konarka and CSEM Brasil. They are also cooperating with the University of Berkeley, USA and participating in a worldwide round-robin study of organic photovoltaic devices and modules, coordinated by professor Krebs. Of the 46 labs worldwide that are involved, UFPR is the only Brazilian partner. Another cooperation is with a Swedish company Albedo.[115]

The interdisciplinary research group GANDES at the Pontifical Catholic University of Rio Grande do Sul (PUCRS) is developing nanomaterials for hydrogen production. They use physical vapour deposition (PVD) to deposit and functionalise a number of materials including platinum and TiO2 with cadmium selenide (CdSe). In the future they plan to work on new materials such as bismuth vanadium oxides (BiVO4) and copper tungsten oxides (CuWO4) to test their absorption of visible light. PUCRS is a private university, which puts a lot of effort into interfacing with others and joint research. They have a laboratory for Microscopy and Microanalysis (CEMM), with electron microscopes (SEM/TEM/STEM) and an atomic force microscope (AFM).[116]

The organic bio-optoelectronic lab at the Technology Institute of Parana (UTFPR) was created in June 2014. They work on applications in solar cells, sensors, LEDs and transistors. They collaborate with others at the Federal Technology University of Parana (UTFPR), Cape Town University in South Africa (which supplies the nanomaterial) and the University of Aveiro, Portugal. Topics of research include solvent annealing induced nanowetting, electrochromic window, production of polymer based batteries, organic solar cells and

[115] C.f. presentation Lucimara Stolz Roman during NMP-DeLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu
[116] C.f. presentation Pedro Migoski da Silva during NMP-DeLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu

sensors. It has a number of microscopes such as HR-SEM, HR-TEM, AFM etc., but still lack ability to probe the morphology at the nanoscale.[117]

Mexico

Nanotechnology for energy applications is carried out in mainly small groups in 30 centres or institutes in 21 institutions all over Mexico. The Secretariat for Energy (SENER) and CONACYT together have funded one project on nanoenergy.

According to an interviewed expert, the University of Guanajuato is working on porous materials as storage media for hydrogen storage. They cooperate with research groups in Italy and France.

According to a participant of the workshop on nanotechnology for water and energy (Monterrey 11/2014), CIMAV, in Monterrey, is focusing on nanotechnology, materials and energy applications and works mainly for external industrial clients. It is working on nanotechnology-enabled energy harvesting devices for mobile devices. It is developing integrated solutions for energy harvesting by combining PV, thermoelectrics and radiofrequency. CIMAV has developed each of these areas separately and has proof of principle and patented applications. On the synthesis of nanomaterials and devices fabrication they are cooperating with others who have those competences. The adjacent incubator offers pilot scale laboratories and manufacturing.

Other Latin American countries

From the 28 Argentinean research groups or projects working on nanotechnology for energy, 21% focus on solar energy, another 21% on catalysis and 19% on storage. Three Chilean research groups were identified that work on energy storage and solar cells (University of Chile) and renewable energy (University of Santiago), respectively. In Colombia, 19 research groups are working on nanoenergy. In Uruguay, 11 groups work on nanotechnology for energy (For more information see Invernizzi et al, 2015).

According to a participant in the workshop on nano for industry (Chile 12/2014), STABLE is an ongoing project on nanotechnology for energy applications in cooperation between the EU and Chile. The project focuses on a Li-air battery based on its own innovation. Using an electrospinning technique, they can produce different architectures that are applied in Li-air batteries for electric cars. It aims to improve the stability of materials from recharging a few times to 100-150 cycles and increasing capacity to over 2000 mAh/g.

Participants in the workshops in Chile and Curitiba (05/2015) reported that three groups in Uruguay work on nanoenergy. There are two strategies for solar cells: silica-based and dye sensitized (Grätzel). The two Uruguayan groups are Polytecnico Pando, Faculty of Chemistry, and Lab of Biomaterials, Faculty of Sciences, at the University of the Republic (UdelaR). One research line modifies the semiconductor through incorporation of TiO_2 nanotubes, which improves surface area and performance of both electrodes. CNTs can also be used and lead to different electrode properties. The other research line is modification of the photoelectrode with natural pigments including Flor de Ceibo, the Uruguayan national flower, as in the original design of the

[117] C.f. presentation Andreia Gerniski Macedo during NMP-DeLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu

Grätzel cell. This is important for reducing production costs and the investment needed for companies to start the business.[118]

Europe

In Europe, an overview of all EU PV projects is available at www.eupvclusters.eu. In particular, the partnership Solliance brings together R&D organizations from the Netherlands, Belgium and Germany who are working on thin film solar PV. Their activities include organic and Perovskite based PV, for which they have the necessary expertise and infrastructure. They are interested to expand their industrial partnership with companies to other countries.

In the Netherlands the national programme NanoNextNL[119] includes a thematic programme on energy applications. Several universities are developing innovative concepts for more efficient or cheaper solar cells. The energy research centre ECN[120] translates these academic research results into proof of principle, pilot production or product demonstration for companies. Universities and ECN cooperate with industry in the Netherlands and Europe that can apply the results in PV products.

In Germany, the SolarValley Mitte Deutschland is a consortium of universities and companies that might be interested in cooperating with partners in LA.

The University of Linz in Austria specialises in designing organic semiconducting materials PV in a network of European and African partners. They are interested in joining forces with Latin American colleagues.

Swansea University, in the United Kingdom, is applying nanotechnology to lab scale and pilot scale membrane separation processes for power cells. They work on nanoscale characterization techniques with specialist expertise in SPM technologies, as well as polymer fabrication techniques for modifying surfaces used in energy generation, including nanoelectrospinning and nanoparticle functionalization. They apply electrospinning to the production of carbon fibres. They have industrial collaboration with international companies and small and medium firms.

In France, the Atomic Energy Centre (CEA) has three research centres relevant to nanotechnology for energy applications: LIST (software, in Paris), LETI and LITEN in Grenoble. LITEN is 10 years old and had 1000 collaborators in 2014. It focuses on energy. In Chambery, the focus is on solar energy and building integration, in Grenoble on green transport and biomass. In Cadarache and Corsica, they have solar demonstrators. The main goal is the production of patents. The budget is €150 million year, including an important sum from industry. They produce large area electronics and nanomaterials, and cooperate with the NanoREG project and with large and small companies. They contribute to the three main categories of solar cells: crystalline Si, thin film and 3rd generation. Nanotechnology plays a role in all three.[121]

International

[118] C.f. presentations of these workshops at www.nmp-dela.eu
[119] www.nanonextnl.nl
[120] www.ecn.nl
[121] C.f. presentation Dr Bertrand Fillon, NMP-DeLA workshop Curitiba, 28-29 May 2015, www.nmp-dela.eu

The African Network for Solar Energy (ANSOLE)[122] aims to foster development of solar energy research and applications in Africa through a web platform and research network of African and international research groups. ANSOLE has over 750 members from 40 African and 23 non-African countries. They are interested in South-South collaboration with LA.

In the USA, at Northwestern University, professor Bob Chang is developing 3rd generation hybrid solar cells, based on Perovskite-based dye sensitized solar cells, a 2012 breakthrough (Nature, 24.05.2012). He also works on supercapacitor integration and plasmonic sensors. His institute is active in basic research and scale up to manufacturing. They are currently able to make large areas with roll-to-roll production and are working in lowering the costs. This should be demonstrated by end of 2014, and then they can start talking to investors. They are is interested in international collaboration in nanotechnology including education with Mexico and other Latin American countries.

The University of Texas at Austin, USA is working on nanocatalysts of molybdenum (Mo) doped with cobalt (Co) to reduce the sulphur content in diesel, and adding vegetal oil (e.g. coconut) to overcome the increased wear due to the limited lubricity of the diesel. They are also interested in international cooperation, especially with Mexico.

7.1.2 Energy Sector Industry and Investment

Invernizzi et al (2015) list eight Brazilian companies developing nanotechnology for energy applications. Zayago et al (2012) have identified one Mexican company in the petrochemical sector that is active in nanotechnology R&D.

According to an interviewed expert, UNESP in Brazil engages in technology transfer of nanomaterials and sensors for solar energy in cooperation with two technology parks in Sao Paulo state, two universities and start-up companies. In addition, an energy start-up in Campinas, Brazil is developing devices for energy conversion and solar cell devices. They are developing their own technology, supported by Brazilian innovation agencies.

The Chilean consultancy Nanotec SA is working on a set of nanotechnology applications based on consumer preferences, including lighter, more flexible, tactile products with better resolution, better storage capacity, faster, more ecological, more resistant, more sustainable, more economic and interconnected. Raw materials used include fine particles, aligned polymers, coatings etc. Applications include plastic electronics for sensors in cars, textiles, energy harvesting, collection and storage of energy, batteries and supercapacitors, and dancefloor energy. It wants to develop products based on molybdenum, lithium, and native flora and fauna.

Another Chilean company, Adrox, has developed transparent self-cleaning coatings for solar panels. This project started 2 years ago in the North of Chile. They are looking for partners that can produce certified TiO_2 nanoparticles in high quantities. They have different coatings, including PowerSun for solar cells, that

[122] www.ansole.org

reduces the water required for cleaning by 80% and increases energy generation by 30%. The coated product is more environmentally sustainable and more profitable than the non-coated product.

In Costa Rica, an expert considers that there is some industrial development in nanotechnology for biofuels and energy, but that they cannot proceed to the next phase by themselves.

In Europe, the ETP Photovoltaics has adapted tools that allow morphological and opto-electronic characterization at nanoscale of dye-sensitized solar cells. In the ETP Renewable Heating and Cooling most nanoactivity is related to energy, according to a participant in the workshop in Monterrey, Mexico.

In the Netherlands, all Dutch companies and knowledge institutes have joined forces in a network engaged in R&D&I in solar PV. They are looking for international partners especially in the BRICS countries (Brazil, Russia, India, China and South Africa), but also in other countries. Franken and Meijer (2014) have analyzed the Unique Selling Point and positions of the Dutch companies in the value chain.

In Austria, the Linz Institute for Organic Solar Cells has an incubator for small high tech spin-off companies. The research focuses on PV, 3rd generation organic and perovskite solar cells.

7.1.3 Policy and Funding on NMP for Energy.

Brazil

The Brazilian government is diversifying its energy matrix and investing in non-hydro renewables including (since 2014) some centralised solar energy for electricity production. The expected demand for new developments is 1 GW, which opens up opportunities for international cooperation in the next five years, in particular in the form of joint ventures with Brazilian-based companies. Foreign partners can contribute applied research, cultural change, education, engineering and logistics, financing, knowledge and technology and policy making (Transfer LBC, 2015).

Invernizzi et al (2015) report the following: In **Brazil,** the base document for the Nanoscience and Nanotechnology Development Programme, incorporated in the 2004-2007 Multi-annual Plan of the MCTI, identified the following research areas as relevant for the country's plan in the field of energy: a) power generation devices - electrodes and membranes for combustible cells; b) storage structures - supercapacitors and new batteries; and c) nano-chemical photovoltaic systems (MCT, 2003, 7). Also in 2008-2011, nanotechnology for the energy sector was a priority in the Multi-Year Plan for STI. The current National Science, Technology and Innovation Strategy 2012-2015 again highlights nanotechnology as a strategic area and places energy among the country's priority sectors.

The research council CNPq is responsible for awarding Brazilian federal funding for nanotechnology and under the Energy sector funds. In 2013, the CNPq budget for energy was R$ 83.33 million (around €21.42 million). The FINEP (Funding Authority for Studies and Projects) promotes R&D in business including energy research as well as nanotechnology. According to an interviewed expert, the Brazilian Ministry of Development and Foreign Commercialization is also involved in nanotechnology policy.

In the Brazilian MCTI, the coordination on renewable energy is under the same coordination as nanotechnology, this makes it easier to cooperate within the Ministry. Brazil is furthermore cooperating with the USA

in the Consortium for Innovation on Nanotechnology, Energy and Materials (CINEMA) programme. The focus is on nanotechnology for energy training and mobility making use of the Science without Borders programme. Involved US labs include Massachusetts Institute of Technology, Stanford, Colorado State University, and University of Colorado at Boulder, School of Mines. The aim is to improve the renewable energy grid in both countries.[123] They are cooperating with the BRICS countries on standards for (O)LEDS.[124]
The CNPq BJT (Bolsa Jovem Talento) fellowship supports repatriating Brazilian scientists, assisting them in starting a group.

Mexico

In CONACYT there was a network and on energy, that has just been restarted. This field is fragmented, according to a participant in the workshop in Monterrey, Mexico.

Uruguay

The Ministry for Industry, Energy and Mining (MIEM) hosts the sector council for nanotechnology. Uruguay has a national investment programme funded by the innovation agency. Foreign postdocs are welcome to apply for a position in Uruguay.[125]

Other countries

In addition to public funding, ANSOLE has demonstrated for African students that crowdfunding and sponsorship could also be a solution for investing in practical training.

7.2 Energy-related Good practices and Recommendations

What are good practices and recommendations for production of NMP-based sustainable energy technologies developed in Europe and LA with a view to fostering international cooperation? This includes national and regional examples of actions for up-scaling innovation in these technologies.

7.2.1 Research targeting NMP for energy

An interviewed expert recommends mapping the field of nanotechnology for energy including international state of the art and trends, as well as Latin American expertise and opportunities for EU-Latin American cooperation. This has been done in NMP-DeLA (Invernizzi et al, 2015) and the main results are summarized in the present roadmap. The expert also recommends organizing follow-up events where European and Latin

[123] http://sciencepolicy.colorado.edu/cinema/index.html
[124] C.f. presentation Anna Tempesta during NMP-DeLA workshop in Curitiba, Brazil, 28-29 May 2015, www.nmp-dela.eu
[125] http://www.miem.gub.uy/consejos-sectoriales/nanotecnologia

American parties can meet physically, exchange knowledge and learn about each other's results and their vision of applications.

The following recommendations were made during the workshop in Curitiba on nanotechnology research for energy:

- If there is no strong manufacturing industry in the region, then researchers should concentrate on lifecycle and stability testing of materials developed elsewhere in the world.
- It is important to generate better understanding of materials behaviour than is available elsewhere worldwide.
- Applications should be developed that meet LA needs.
- There are more opportunities for PhD students than merely targeting jobs in manufacturing. It is a highly competitive sector. Alternative tasks include testing devices and putting them in analytic tools, and understanding the way to market.
- In LA, the bio based industry is well developed. Endemic nanomaterials could offer opportunities for new coatings which are sustainable rather than based on fossil fuels. PETROBRAS could be a partner in this. Using the national flower of Uruguay could offer symbolic value and opportunities for science communication.
- If the government wants to have industrial development, one expert advised to invest in research and knowledge development and not manufacturing related questions in the absence of a manufacturing industry. Instead, it may be better to team up with companies in other countries in research that has a relation with potential applications. There could be more to be gained there in the long term using this alternative. Educational interests maintain the ecosystem and fosters experts to do research in the field. The university should focus on understanding the problems needed to later develop an application. It is advisable to publish papers and find commercial partners to develop new things.[126]

In Costa Rica, an expert recommended building up the human capacity for nanoresearch in the short term.This should be done through international cooperation with Europe, in particular Germany and Italy.

7.2.2 Policy and Funding for NMP for Energy

Chile

According to a participant in the NMP-DeLA workshop (12/2014), Chile could benefit from a Smart Specialization programme as fostered by the EU, taking into account its modest and limited public funds for innovation at national, meso-regional and regional level. Three national programmes have started in the national interest including one on solar industry, because Chile lacks fossil fuels and the desert region in the North is characterised by lots of sunshine.

[126] This position can be criticized and does not represent a consensus view from the meeting.

7.2.3 Energy Sector Industry and Investment

One recommendation that came out of the workshops was that there should be stronger and longer-term industrial focused collaboration between LA companies and companies in other countries which could include research institutes. This should focus on thin-film technologies and support technology transfer, industrial implementation and manufacture.

Another expert discussed niche markets for nano-energy in LA. In the long term, people will want integrated devices for health or water monitoring or others, that will be based on high energy density Li-ion batteries, that are very light and use Wi-Fi technology. These could have applications in environmental and agricultural monitoring. This expert recommended targeting Brazilian niche markets for nanotechnology for energy in the agribusiness, such as solar panels to control monitoring devices for crop growth. Other applications could include drug (or pesticides) delivery for better pesticide applications in agriculture reducing pollution and also water and soil monitoring devices. These devices have to be self-sustaining in terms of energy.

7.2.4 Energy-related education and training

An expert recommended building capacity through education and training. Academics should be taught in English, but vocational training for technicians and entrepreneurs should be offered in Spanish and Portuguese. Awareness about climate change and energy issues should be raised among the local population using performing art in local languages. For this, it is important to understand social and cultural aspects of local communities.

Another expert recommended to network and cooperate to spread achievements in nanotechnology to high school students. He said that in Europe it is difficult to get young students to become interested in nanotechnology and they need to be shown interesting research that may give them a chance to save the planet. But we mostly start too late in integrating Science and Technology in the education curriculum. In Brazil there is no information for young students in books, whereas Germany has great materials for all levels.

7.3 Producing technologies and applications in the future

How can solutions, technologies and applications be produced in the future for production of NMP-based sustainable energy technologies developed in Europe and LA with a view to fostering international cooperation? This includes solutions needed, timeframe for implementation and action steps (at national, EU and LA level) for developing the technologies in LA.

7.3.1 Research targeting NMP for Energy

Progress in solar PhotoVoltaics is coordinated globally by the Solar PV roadmap published by NREL[127]
In Europe, the EU Photovoltaic Technology Platform organizes research organizations and industry interested in innovation in PV technologies. The latest version of their Strategic Research Agenda (SRA) aims at considerable cost reduction for solar energy equipment by 2030. Even though nanotechnology for solar energy is not addressed in a separate chapter, several nanomaterials are included as options in the SRA. One of these options is thin film technologies, where processes and equipment for low-cost, large-area plasma deposition of micro/nanocrystalline silicon solar cells are envisaged. Organic PV requires further fundamental research and understanding of the physics of the dyes including the effect of nano-morphology and order on charge transport within the cell. Novel PV technologies may be developed if new methods for nanoparticle synthesis become available (EU PV Platform, 2011).
From the nanotechnology side, the Dutch national nanotechnology programme NanoNextNL (2011-2016) includes research focusing on applications of nanotechnology in efficient generation of sustainable energy as one of the four key application areas. The Strategic Research Agenda includes an overview of Dutch research organizations and companies active in nanotechnology for energy applications including solar, wind, biomass, fuel cells, hydrogen storage, energy saving, batteries and fossil energy. It proposes the following research lines:

- The efficient generation of sustainable (solar) energy
- Solar energy for generating heat
- Solar energy production of fuels
- Wind energy
- Efficient energy consumption through the secondary conversion of energy and the separation of substances
- Nanotechnology for energy storage
- Inorganic and organic LEDS with extremely high efficiency (NanoNed, 2009)

The current NanoNextNL[128] programme includes two thematic programmes related to energy: efficient generation of sustainable energy and efficient energy utilization by secondary conversion of energy and separation.
According to an interviewed expert, nanotechnology for solar energy can be applied in more efficient, cheaper solar panels, adapted solar panels, such as transparent, light weight, coloured or flexible solar panels.
According to Wim Sinke,[129] current breakthroughs in PV will lead to much higher efficiencies while reducing costs dramatically. Nanotechnology provides opportunities for efficient and low cost PV, but the competition from mature PV is fierce. It is better to focus on improving the established PV and creating novel applications.

[127] http://www.nrel.gov/pv/
[128] www.nanonextnl.nl
[129] In his presentation during the NMP-DeLA workshop in Curitiba, 28-29 May 2015, www.nmp-dela.eu Details are included in the powerpoint slides posted on the website.

7.3.2 Policy and Funding for NMP for Energy

Brazil

According to an interviewed expert, the Brazilian government may foster nano-innovation for energy applications. In terms of bioenergy and energy for local use, such as agribusiness in remote areas, there is a need for a self-sustaining local energy supply. There are opportunities for joint ventures between foreign companies and Brazilian companies. One way to stimulate local development is to establish projects with local companies or local research council funding.

Mexico

In Texas, shale gas fracking is taking place in Eagleford. This gas reserve is continuing throughout Mexico until Veracruz. It will be exploited according to a participant in the workshop on nanotechnology for energy in Monterrey, Mexico. This is a relevant development affecting general energy policies in the country that may have implications for the chances to develop applications of NMP for energy solutions.

Europe

The strategic research agenda for PV includes an implementation plan for Solar World industries in the next 4-5 years. The European Commission recently published a strategic energy technology roadmap.[130] The key message from this is not to optimise individual technologies, but look at the interactions, and consider that heating and cooling, and generation of fuels will also be done with solar PV.[131] Nanotechnology and nanomaterials are included as a key enabling technology for Solar PV electricity generation, Carbon Capture and Storage in power generation, and bioenergy for power and heat generation in the 2013 Technology Map of the SET-PLAN (JRC, 2013).

7.3.3 Energy Sector Industry and Investment

In a study published by Bloomberg, solar has become cost-competitive with other forms of electricity generation since 2012.[132] For example, the generation costs for solar energy in Europe are as low as €0.02-0.05 per kWh (Mayer et al, 2015).

In the view of an expert, it is considered that thin film PV will become the successor of classic multi-crystalline Si PV. Thin film PV will allow much better integration of PV in buildings, vehicles, urban furniture, etc. However, in order for this to happen, the technology needs to progress further. By joining forces, the progress can be accelerated in this field.

[130] http://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan
[131] http://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan
[132] http://www.bloombergview.com/quicktake/solar-energy

According to another interviewed expert, solar energy companies could develop PV installations with adequate energy storage capacity for charging cell phones and other energy need in remote regions. Their awareness should be raised concerning appropriate technology to address local needs. Brazilian energy companies cooperating with UNESP are interested in developing batteries, energy storage devices, and lithium ion batteries in Brazil. The University of Cornell, USA has developed Li-ion batteries in high energy format for mobile device batteries, e.g. google glass. They are interested in establishing a subsidiary in Brazil.
According to another interviewed expert, Dutch equipment manufacturing companies are setting up factories and production lines for solar energy. These companies may be interested in applications of nanotechnology if there is a market for these products in LA. Likewise, solar energy companies may be interested in the Latin American market for solar energy in general if it is a growth market.

In Costa Rica, an expert foresees market niches in nanostructured materials for energy including hydrogen storage and modification and enhancement of biofuels for higher efficiency.

7.3.4 Energy-related Ethical, Legal and Societal Aspects

According to interviewed experts, in the long term, nanotechnology could contribute to solutions for climate change, energy for all including access in remote areas and improved energy security through reduced dependence on imports of fossil fuels in some countries.

8 Nanosafety

8.1 State of the Art

How is NMP deployed (now) in the context of societal challenges in the field of health for applications targeting nanosafety developed in Europe and LA with a view to fostering international cooperation? This includes existing solutions identified for improving the capacity to develop innovative nanosafety solutions in LA, and their stage of development.

8.1.1 Research on nanosafety

One interviewed expert summarises the state of the art in nanosafety as follows: *"artificial exposure scenarios are studied in the laboratory or contaminated samples from industry are tested, measurements focus on the numbers of particles and chronic effects of exposure to chemicals are still largely unknown".* Notwithstanding this bleak assessment, a lot of efforts are undertaken to generate knowledge on nanosafety, coordinated by the OECD Working Party on Manufactured Nanomaterials (WPMN) and ISO technical committee

TC229. In these international collaborations the EU (through its nanosafety cluster)[133] and USA play leading roles.

NMP-DeLA Community of interest members are involved in the following research topics related to nanosafety:

At national level, in Brazil, six nanotoxicology networks coordinate research on nanosafety.[134] The focus areas include:

- Aquatic nanotoxicology,
- Toxicology of nanocomposites and products,
- Nanoparticles in oil and paint,
- Occupational and ambient nanotoxicology,
- Standardisation and the development of reference materials, and
- Applications in agrifood and health.

Fiocruz is a key applied research centre in this field. They work on the following topics:

- Filters using natural proteins for water purification, to increase the lifetime of existing products.
- Nanotoxicology, aiming to understand the link between exposure to carbon nanomaterials and cardiovascular / arrhythmia and respiratory diseases, cancer.
- Worker protection against exposure to nanofibres, CNT.
- Nanotoxicology for consumer protection
- Study environmental exposure in the lab and worker exposure in industry in cooperation with WHO, UN, NIOSH, Portugal.

Specific academic research centres include the University of San Carlos, Department of Materials, which works on toxicology of chemicals in existing contacts with the USA, China and Japan.

In Cuba during the embargo, the national research community has been working in isolation on nanosafety for medicine and agriculture or food safety. The programme aims at social development of medicine with a focus on ethics and benefit sharing.

In Austria, PLUS, Immunology and Allergy Division at the Department of Molecular Biology in Salzburg works on nanosafety by studying the immune system for worker / consumer safety: they study artificial exposure scenarios. They also work on standardization, regulation, and workplace safety in the NanoValid project, which includes the Brazilian metrology institute (INMETRO).

In the UK, Heriot Watt University (HWU) works on environmental effects and ecotoxicology of chemicals including nanomaterials. They study environmental impacts, hazard, exposure tests in whole organisms and cell cultures in their laboratory: fish, daphnia, worms, algae, microbes, nematodes, snails and others. They cooperate with EU scientific committees: Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), Scientific Committee on Health and Environmental Risks (SCHER), Organization for Economic Cooperation and Development (OECD) and have contacts with the Argentinean government, Brazil, Venezuela (SETAC 2011). They also participate in the Nanosolutions project with Brazilian partners.

[133] www.nanosafetycluster.eu

[134] http://www.nmp-dela.eu/ExpertWorkshopPresentations/05NanoBrazil1.pdf

The International Water Association (IWA) has a specialist group on nanotechnology, which mainly focusses on environmental risks of nanomaterials in water. Likewise, the Society of Environmental Toxicology and Chemistry (SETAC) has a working group on nanotechnology. The GWRC (Global Water Research Coalition) is also active in this field.

EU projects also foster research in this area, and are coordinated through the European Nanosafety Cluster[135]. One relevant project is NANOPUR, which is developing functionalized nanostructured polymeric membranes and related manufacturing processes for water purification. The European Water Supply and Sanitation Platform WSSTP has an emerging compounds group looking at nanopollutants in water.

NMP-DeLA Community of Interest members are active in the following research activities in environmental nanosafety:

- KWR Water Cycle Institute in the Netherlands is developing analytical methods for organic and inorganic nanochemicals. They apply this in monitoring water quality during water purification (drinking & waste water) to establish the removal efficiency. They also study the fate of nanomaterials in the environment.
- IDAEA in Spain has been studying the fate, behaviour and risks of fullerenes and other carbon based materials in the environment, focusing on the Trojan effect of interactions between different nanomaterials. Locations investigated include the land around oil production sites in Brazil.
- CINVESTAV in Mexico is studying the toxicity of nanoparticles used in photovoltaic cells (e.g. CdS, CIGS, Bi) through *in vitro* and *in vivo* studies (BISNANO project) in cooperation with a research group in Dublin.
- The University of Texas at El Paso, USA[136] is studying biotransformations of nanoparticles through synchrotron studies in interdisciplinary and international networks. Topics include CeO2 and ZnO in soybean and other food plants.
- CIMAV in Monterrey, Mexico carries out risk and control / monitoring of pollution tests for companies. The focus is on risk and control / monitoring of pollution. However, they are not yet accredited.

8.1.2 Policy and funding for nanosafety

The European Union has invested €137 million in nanosafety research in the past 6th (13 projects, €31M) and 7th (34 projects, €106M) Framework Programme for RTD. Current public-private funding includes €50 million in the NanoREG project (10 from the EU and the rest from national and private funding).

Emerging markets including Brazil and Mexico already have adopted Occupational Safety and Health (OSH) regulation. The main current issue for policy makers is how to verify compliance to these general rules. In

135 www.nanosafetycluster.eu
136 http://www.ssslogic.com/gardea/

addition to the existing general OSH regulations, there is interest in cooperation aiming at incorporating nano in these regulations. The WHO Healthy Workplace programme could be the starting point to achieve this. In this WHO programme, 12 global experts advise on occupational health and safety regulation. These are valid for all UN Member States. The European Nanosafety Cluster is opening up to international partners.[137] In particular, Brazil has joined the European NanoREG project.[138]

8.1.3 Industry and Investment targeting nanosafety

Some interviewed Community of Interest members see a niche market for nanosafety instruments or tools, in Europe as well as LA. For example, a Dutch start-up company offers an online chemical substance management tool and is interested in developing a Spanish version in cooperation with local partners in Spain and LA. In the future this tool may also cover nanomaterials.

8.1.4 Responsible Research and Innovation aspects of nanosafety

The OECD is monitoring developments in national regulation covering manufactured nanomaterials (OECD, 2014a). Submissions from Australia, Canada, Denmark, the EU, France, Germany, Italy, The Netherlands and the USA indicate that existing regulatory frameworks are used to cover nanomaterials. Some countries have developed reporting regimes for nanomaterials to gather information about the quantities and applications of nanomaterials on the market. Latin American countries have not contributed to this study.
The Mexican Secretary of Economy has issued guidelines for regulating nanotechnologies in November 2012 as part of a bilateral agreement with the USA. Foladori and Lau (2014) criticise the content of the Mexican guidelines for regulation nanomaterials for being imposed by the USA to facilitate trade in products with nanomaterials.
According to an NMP-DeLA Community member, there are no companies that communicate about nanosafety in Mexico. There are problems with awareness and worker safety. The Mexican Work Secretariat is not engaged in nano. In the regulatory process, there is more activity on environmental issues, but this has resulted in recommendations more than rules, and laws are not being revised.

8.2 Good practices and Recommendations targeting nanosafety

What are good practices and recommendations for applications targeting nanosafety developed in Europe and LA with a view to fostering international cooperation? This includes national and regional examples of actions for scaling-up innovation in these applications.

137 www.nanosafetycluster.eu
138 www.nanoreg.eu

8.2.1 Research on nanosafety

Good practices: The European/American Nanosafety Research Agendas and the EU-funded ITS-Nano project have contributed to an internationally coordinated strategy. In addition, the level of expertise in nanosafety from biologists and nanomaterial scientists in Colombia, Argentina and Venezuela is high. The EU Nanosafety Cluster represents good practice in this area of research and cooperation with LA should be encouraged through European partners during the NMP-DeLA project.

Recommendations: Stakeholders in nanosafety should be defined that include regulatory agencies, industry associations and researchers on nanosafety. These should be brought together through a physical meeting to start with and a white paper drafted that details how to proceed with the integration of European and Latin American efforts. In the longer term, Latin American nanosafety experts should be offered access to infrastructure and equipment and training, e.g. in the European facilities. Priorities in research include the following:

- Establish a partnership between scientific disciplines in this field. Challenges include developing and sharing experimental protocols, including for exposure assessment, and reference materials;
- Study exposure to nanomaterials throughout the life cycle of consumer products;
- Study chronic profiles and different exposure routes (e.g. inhalation);
- Study exposure to food that contains nanostructured ingredients;
- Study links between exposure to nanoparticles and diseases for different groups (workers, consumers, adults, children, etc);
- Develop new methods for epidemiology.

8.2.2 Policy and funding for nanosafety

Recommendation: Latin American countries other than Brazil should also fund longer term collaboration in nanosafety.

A global approach to nanosafety is needed. This requires development of a common roadmap of evolving solutions for a variety of nanomaterials that are or could be used by industry. In addition, a better understanding is needed of different preoccupations with risks (e.g. GMOs) between European consumers and American and Asian consumers.

8.2.3 Industry and Investment targeting nanosafety

Good practice: A feasibility study by NIOSH for biodegradable CNT offers a good example of safety by design. Brazil invests in EU-Latin American research collaboration in nanosafety.

Recommendations: In 3-5 years, data should be available for internet tools that support nanosafety at work. It is recommended to develop a business plan that will ensure that this platform continues after the end of the funding. Safety by design should be fostered by producing engineered nanomaterials that can be absorbed by the body.

8.2.4 Responsible Research and Innovation aspects of nanosafety

According to participants in the NMP-DeLA project, there is a need for theoretical life cycle models for products containing nanomaterials to determine the final fate of these materials after the product's useful life (including environmental fate). This should be a sustainable and positive endeavour engaging all stakeholders from Latin America, Europe and other parts of the world. The way forward leads via technological networks and social actions to engage the local population and companies in innovation and communication. A key question is "How to remove the pollution including nanomaterials from the environment including water, air and soil?" It is important to foresee what will be the most important polluters in order to develop clean nanomaterials.

8.3 Producing technologies and applications in the future

How can solutions, technologies and applications be produced in the future for nanomedicine applications targeting nanosafety developed in Europe and LA with a view to fostering international cooperation? This includes solutions needed, timeframe for implementation and action steps (at national, EU and LA level) for developing applications in LA.

8.3.1 Research on nanosafety

The Strategic Research Agenda 2015-2025 of the European Nanosafety Cluster sets targets for research in Environment, Health and Safety aspects of engineered nanomaterials. Future research priorities in the EU Nanosafety Cluster include discussing the development of measurement methods for real life exposure to nanomaterials for the purpose of protecting worker and consumer safety. It is necessary to adopt standard protocols and to disseminate information on the correct methodology in the nano-risk assessment community (Savolainen et al. 2013). Another long term idea for a radical innovation mentioned by an NMP-DeLA Community of Interest member is to develop a "carcinogen counter" as simple and easy to use as a Geiger counter for radioactivity. This should be applicable to nanomaterials as well as other chemicals with carcinogenic properties. This rather futuristic suggestion fits with the recent change in EU strategy from funding stand-alone nanosafety research, to integrating nanosafety in larger enterprises and innovation initiatives.
Opportunities in LA are offered by the Cuban research community, which has developed its own nanosafety methods and is interested in establishing cooperation after the end of the embargo, in particular with France. The Brazilian INMETRO research centre has its own budget for nanosafety research.

8.3.2 Policy and funding for nanosafety

At the global level, the WHO includes nano in its Healthy Workplace Programme in the form of occupational health and safety regulation/guidelines for nanomaterials. Government departments across the globe should apply occupational health and safety rules, manage production, educate workers, fund risk assessment, and discuss social issues. The OECD Working Party on Manufactured Nanomaterials (OECD WPMN) is coordinating international governance and a common research strategy in nanosafety.[139]

In Mexico, the Federal Secretariat for Economy is looking into regulation and exposure reduction for nanomaterials.

8.3.3 Industry and Investment targeting nanosafety

In LA as well as in Europe, there may be local market opportunities for a service industry offering nanosafety evaluations for industry. Potential applications are monitoring safety at the workplace, consumer safety, safety by design and failing fast and cheaply (allowing rapid iterations), and following the example of the pharmaceutical industry: quality by design. Similarly, another university is already advising industry about safety by design. A Dutch tool for managing occupational health and safety of chemicals could be adapted to Spanish speaking markets. There could be an opportunity for local partners to deliver consultancy related to the online tool.

9 Impact indicators: NMP DeLA Approach to assess impacts of nanotechnologies on societal challenges in health, energy and water

9.1 Indicators: can`t do without

Actions suggested by the NMP DeLA Roadmap are directed towards using nanotechnologies to create positive impacts on societal challenges in the areas of health, energy and water.

In the framework of NMP DeLA we do not have the opportunity to implement a social impact assessment of a nanotechnology intervention. However, we want to illustrate possible implementation modalities of such an assessment where we focus on the development of impact indicators.

Indicators are signposts for change and allow us to contrast a target of an intervention (what one hopes to achieve) with a baseline (initial status before the intervention).

“Indicators are quantitative or qualitative variables that allow the verification of changes produced by a development intervention relative to what was planned.” (UNDG RBM Handbook, 2011)

[139] http://www.oecd.org/env/ehs/nanosafety/

In this roadmap we suggest a number of outcome and impact indicators for nano-water, nano-energy and nano-health (although most may work for other application areas as well). In a classical result chain the logical cause-and-effect relation runs from inputs to impacts.

IMPLEMENTATION		RESULTS		
Inputs ➔	Activities ➔	Outputs ➔	Outcomes ➔	Impact

Outcomes are short-term effects, which are directly attributable to an intervention and by definition more narrow than impacts. Several intermediate outcome indicators may support the assessment of the final outcome, which then leads to the impact.

The United Nations define impact as follows:

“Impact implies change in people’s lives. This might include changes in knowledge, skills, behaviour, health or living conditions for children, adults, families or communities. Such changes are positive or negative long-term effects on identifiable population groups produced by a development intervention, directly or indirectly, intended or unintended. These effects can be economic, socio-cultural, institutional, environmental, technological or of other types. Positive impacts should have some relationship to the Millennium Development Goals, internationally agreed goals, national development goals, and national commitments to international conventions or treaties.”[140]

Nanotechnology is an emerging field, and so the development of indicators for nanotechnology is becoming more prominent. The OECD’s Directorate for Science Technology and Innovation (DSTI) produced an updated version on nanotechnology indicators in 2014 (including data for Mexico and Brazil). Other references for general nanotechnology indicators are found e.g. in the OECD Science and Industry Scoreboard. What these indicators primarily measure are numbers of (small) firms in nanotechnology, nanotechnology in R&D expenditure in different sectors (private, public, and education) and nanotechnology patents. Another important source of information are peer-reviewed publications, e.g. the ObservatoryNANO Briefing No.20 “Patents: an indicator of nanotechnology innovation[141] ”.

In most cases assessments of the implementation of nanotechnology projects are done through cost-effectiveness analysis.

There have also been attempts to find indicators for socio-economic and environmental impacts of nanotechnologies. According to the OECD some validated approaches to evaluate environmental and social impacts of these technologies exist, such as multi-criteria analysis or the sustainable water resources management and planning approach[142] . Furthermore, there has been a demand for the assessment of societal implications of nanotechnology, which, according to P. Shapira, added new clusters of nanotechnology spe-

[140] Result-based management. Handbook. Harmonizing RBM concepts and approaches for improved development results at country level, UNDP, October 2011, p.7
[141] see: http://bwcv.es/observatorynano/observatorynano-delivered-briefings
[142] Fostering Nanotechnology to address global challenges: Water, p.39, OECD 2011

cific knowledge (e.g. in public perception, ethics, governance and science mapping)[143] . Nevertheless the evaluation of social impacts remains difficult and sets of indicators may not be applicable in many cases, because often they assume a linear causal relation between nanotechnological innovation and impacts[144]. A crucial factor for social appropriation of a new technology is e.g. if a community manages to adopt new behaviour in order to integrate the new technology into social practice. It is essential to recognize that impacts are not produced by the technology developers, but rather by users of technology and by dynamics that occur in the process of appropriation of technologies by societies. Impacts are therefore extremely context dependent.

Nevertheless a firm evidence base for nanotechnology impacts must be established in order to support and advise policy making and implementation[145] . Region specific case studies on impacts of planned implementations of nanotechnology infrastructures are a way forward. There are opportunities for international cooperation in the establishment of a strong evidence base on characteristics and likely impacts of nanoparticles and nanotechnologies in general[146] .

Ultimately, the choice of indicators for a specific impact evaluation is a very sensible task and the selection criteria determine the result and quality of the evaluation to a great extent and may have unforeseeable consequences on decision making. The choice of indicators also depends on the evaluator's understanding of the cause-and-effect chain of the intervention or the "theory of change" lying behind the purpose of the intervention. Therefore, we suggest that definition and selection of indicators should be done by a bottom-up process with the involvement of relevant stakeholders, and that the indicators should be tested against practical use (realism in choice!). Ruby Sandhu-Rojon describes the following steps in the process of selecting indicators: (1) brainstorming ideas, (2) assessing each one and narrowing the list and (3) making an indicator monitoring plan[147] . Building partnerships and cooperation for the sharing of indicators may distribute workload and contribute to finding agreement.

Well established sets of criteria exist upon which indicators may be selected (e.g. SMART criteria, observational criteria, etc.) which will not be discussed in detail here.

RRI indicators:

In our indicator development we want to give some special attention to a report on "Indicators for promoting and monitoring Responsible Research and Innovation"[148] which was recently drafted by an expert group on "Policy Indicators for Responsible Research and Innovation" and published in 2015 by the European Commission. The purpose of RRI policy is to help achieve solutions for current societal challenges (including health, clean energy, etc.) through interaction with relevant stakeholders in

[143] Shapira, P., Youtie, J., Porter, A.L. (2009): The emergence of social science research on nanotechnology, published online: 25 March 2010
[144] Indications of Socio-Economic Impacts of Nanotechnologies: The Approach of Impact Pathways Douglas K. R. ROBINSONa,b and Arie RIPa,ca TEQNODE Limited, Paris
[145] Fostering Nanotechnology to address global challenges: Water, p.39, OECD 2011
[146] Fostering Nanotechnology to address global challenges: Water, p.39, OECD 2011
[147] Selecting indicators for impact evaluation, Ruby Sandhu-Rojon, UNDP
[148] Indicators for promoting and monitoring Responsible Research and Innovation. Report from the Expert Group on Policy Indicators for Responsible Research and Innovation, EC - Directorate - General for Research and Innovation Science with and for Society, 2015, EUR 26866 EN

society. The governance of science and innovation become central in this process. The report uses a concept of impact evaluation where the interaction in the network in which R&I takes place is a crucial factor for change processes.

The report primarily gives recommendation of how to assess impacts of RRI initiatives, but argues that the RRI indicators can be relevant to a number of policy levels and contexts. As our Roadmap is built upon a bottom-up concept that strongly believes in stakeholder involvement, we consider the RRI indicators relevant for this document.

The RRI expert group proposes monitoring indicators for eight criteria of RRI which are (1) governance, (2) public engagement, (3) gender equality, (4) science education, (5) open access/open science, (6) ethics, (7) sustainability and (8) social justice/inclusion. They propose a list of 100 process indicators and outcome indicators for each of these eight criteria. As RRI is understood as a cross-cutting principle of Horizon 2020, the expert group advises that indicators for all eight RRI criteria are included in the development of indicator sets.

9.2 NMP DeLA outreach and impact indicators for nano-health, nano-energy & nano-water

The following list of indicators has been developed on the basis of recommendations that arose from our qualitative research (expert interviews and focus groups). It reflects opinions and priorities of stakeholder who we involved in our research and does not claim to be complete. The indicators are a mix of quantitative indicators (represented by a number, percentage or ratio) and qualitative indicators (represented by perception, opinion or judgement). We clustered the indicators according to fields of intervention. The described impacts cover positive and (to a lesser extent) negative impacts. The indicators are on a very general level and do not address very specific societal challenges in health, energy or water. This is for three reasons: (1) most nanotechnology developments in those areas are at an initial stage and we wanted to avoid being too speculative about their impacts, (2) we wanted to give an overview of indicators which work for all three areas and (3) discussions with stakeholders (no matter which application area of nanotechnologies they represented) radiated around exactly these dimensions of impacts which we will describe.

Finally, we want to point out that in NMP DeLA we did not have the opportunity to test any of the presented indicators.

Indicators in RESEARCH

Recommendation	Indicator	Outcome/Impact
Definition of national research strategies for nanotechnology in LA countries where not yet existing (including research priorities according to local needs and technological capabilities)	• Existence of national research strategy (yes/no) • No. of national NMP programmes that include region-wide priorities • No. of joint calls in the defined priorities • Existence of evaluation instruments on national research strategies (yes/no)	• More efficient use of resources • More visibility of high impact problems in LA • Better integration of less advanced regions/states • Moving resources from "interesting/prestigious" to "most useful to solve problems" • Enhanced south-south cooperation in defined priority fields
Offering newest infrastructure and services for RTD in big nano or data centres	• No. of nanotechnology centres • No. of employees • Geographical coverage • Amount and quality of equipment • Access to external stakeholders	• Knowledge hubs • More opportunities for small labs and labs in peripheral regions • Cost efficiency • Reduced flexibility for scientific personnel (dependence on working hours and qualification of technical staff at site)
Promotion of inter/trans-disciplinary research on nanotechnologies	• % of interdisciplinary publications • No. of interdisciplinary university courses • No. of social science publications on nano-	• Transversal crossing of intelligence • Transparency & openness • Diversity of perspectives

	technology • No. of interdisciplinary advisory or service bodies	• More attention to societal impact • New clusters of knowledge
Intensification of international collaborations in nanotechnology research	• % of co- publications, co-patenting • % of LA speakers at international nano conferences • % of LA researchers publishing in English • No. of cooperation projects • No. of international university outbounds & inbounds	• International visibility • Opening-up of new sources of funding • Shared resources, mutual learning • Domination of global over regional/local problems
Attract more female researchers	• % of funding modalities which include gender requirements • % of research institutes with specific gender actions • % of women in NMP research groups • % of female authors of NMP research papers • % of women who lead a research or advisory groups	• gender equality • change in perception of gender roles in science

Indicators in NANOSAFETY & RISK MANAGEMENT

Recommendation	Indicator	Outcome/Impact

Establishment of a LA Nanosafety Cluster (linked to the European Nanosafety Cluster)	• No. of members (per stakeholder group) • No. of member countries • Publication of a white paper on nanosafety (yes/no) • Contribution to or adoption of international methods and standards on safety and risk assessment.	• Connectivity between experts with complementary capabilities to pursue common objectives • Local capacity building for controlling safety of NMP products and workplaces • Higher safety for workers and consumers
Establishment of national working parties that advise governments on occupational health and safety issues.	• Nature of governance: guidelines (voluntary) or legislation (mandatory) • No. of organisations that implement safety guidelines • No. of trainings on nanosafety	• Increase of work safety • Binding occupational health and safety regulation guidelines for nanomaterials
Binding regulatory frameworks for academia and industry	• Existence of an independent supervisory authority to ensure compliance of standards (yes/no) • Established sanctions (yes/no)	• Accidents and risks are reduced • More Trust in technology • All actors feel committed

Indicators in SKILL DEVELOPMENT

Recommendation	Indicator	Impact
Nanotechnology content in curricula meets the present and future needs of industry and research	• No. of curricula with up to date nanotechnology content • No. of collaborative academia-industry theses on nanotechnology	LA can meet the regional demand for specialized NMP personnel
Introduce Responsible Research and Innovation (RRI) into nanotechnology curricula	Adoption of new curricula which involve RRI (yes/no)	• Growing knowledge base for RRI • More commitment to RRI
Generate expertise in technology transfer with the focus on the peculiarities of nanotechnology (multidisciplinary understanding of the technology, multi-dimensional impacts, etc.)	• No. of experts in technology transfer & nanotechnology • No. of cases of successful technology transfer • No. of start-ups that can commercialize their products	• Scaling-up of R&D • Economic growth • New employment opportunities

Indicators in POLICY MAKING & FUNDING

Recommendation	Indicator	Outcome/Impact
National bottom-up nanotechnology initiative on the premises of RRI	• Existence of explicit national nanotechnology policies (yes/no) • Instruments in place for the support of nanotechnology and nanoscience (yes/no)	• Clear messages produce coherent developments • Exposure of full technological potential • Technological maturity

	• Existence of sustained nanotechnology community with publication records with bibliometric impact (yes/no)	• New products and services are safe, they maximise societal benefit and minimise negative impacts
Implementation of an instrument to finance joint research in regional priority areas	• Existence of regional pool of funding for NMP research (yes/no)	greater number of breakthroughs/advances in priority areas than observed in individual regions
Promotion of broader stakeholder involvement in NMP policy debate (e.g. include technical schools, pharmaceutical companies, patent lawyers, etc.)	• Existence of national nanotechnology platform (yes/no) • No. of multi-stakeholder events/debates in NMP	• Multi-perspective solutions to complex societal challenges • Greater responsiveness and flexibility within NMP networks • Connection of currently disconnected information and knowledge • Greater support amongst wider society for NMP R&D
More explicit promotion of and funding for patent development, commercialization and industrial partnerships	• Level national funding for patent developments • Adapted time horizons of R&D funding (patent development needs more time than publications) • Existence of incentives for innovation (yes/no)	• NMP research becomes integrated in new products and services • Greater opportunities for high-skilled workers • Greater number of high-skilled jobs • Greater export opportunities

	• Number of start-ups based on outcomes of NMP research • Higher Technology Readiness Level (TRL) outcomes • Number of patents relative to number of researchers and/or funding improves	
Development of national strategies to enhance the participation of international companies in R&D activities in LA	• % of investment of international companies in R&D in LA • % of private investment in start-ups and incubators • Establishment of favourable IP sharing (yes/no) • Number of international companies establishing sites/subsidiaries in LA	• Economic growth • LA becomes more attractive to multinationals to establish R&D facilities and manufacturing plants
Increase Venture Capital funding for NMP research and innovation	No. of new start-ups	• Larger investments, IPOs, licensing and mergers and acquisitions • Greater No. of skilled and highly paid jobs

Indicators in APPLICATION & INDUSTRY

Recommendation	Indicator	Impact
Stronger university-industry-government collaborations	• No. of industry-academia partnerships • Increased BERD	• Economic growth • LA becomes attractive place for multinationals to invest in
More investment in the technology implementation process	• % of time spent on testing, adapting, improving, finding partners, etc. • Greater number of new products and services based on NMP – that comply with standards	• Enhanced public acceptance of NMP technologies • Safer and better products
More technological projects based on joint ventures and business planning	• % of approved projects • No. of joint ventures between established LA companies and EU companies • Amount of local investment (public & private) • Nano specific IP generated	• Locally produced technologies and products for niche sectors and local demand • European investors benefit from markets with little competition • LA becomes attractive place for multinationals to invest in • Greater numbers of skilled and highly paid jobs
Establishment of regional networks for innovation & technology transfer	• Investment per country into joint initiatives as percentage of overall RTD budget • No. of beneficiaries per country who receive assistance • Technology Readiness Level	• Long-term collaborations between countries • Value-added in the region • RTD leading to exploitation by participants across the region

Indicators in ELSA, RRI & PUBLIC ENGAGEMENT

Recommendation	Indicator	Impact
Establishment of RRI committee for NMP programming	• Existence of integrated RRI committees in R&D programmes (yes/no) • Occurrence of RRI training/education • No. of RRI policies • No. of RRI agreements • Adaptation of R&D or funding priorities according to RRI	Societally desirable, sustainable and ethically acceptable research
Clarity on and evidence for the time-lines for product development, and likely impacts	• Existence of Incentives/institutional structures for the review of the quality of claims (yes/no) • % of futuristic/speculative publications	• Reduction of speculation and speculative ethics • Clearer results from more specific interaction between ethicists and scientists • More meaningful public debate on actual (not hypothetical) developments • Greater public confidence in NMP developments
LA countries should consider joining the Patent Cooperation Treaty (PCT)	No. of LA countries signed PCT	• Equal opportunities • Independence from bi-lateral agreements
LA governments should evaluate the signing of	• No. of agreements signed	Extended knowledge transfer

confidence agreements or Material Transfer Agreements (MTA) and improve the conditions according to their needs		
Provide regular compulsory training for personnel of regulatory bodies and information channels on latest international developments in nanotechnology regulation	• % of personnel with continuous professional development (CPD) on regulatory issues • Existence of an online Helpdesk (yes/no) • Existence of an Information platform on nanotechnology regulation (yes/no)	• Highly responsive regulatory organs • Error prevention • Well informed researchers • Greater public confidence • Greater transparency
Awareness and information campaign	• No. of outreach activities / media coverage • Types of outreach activity • % of people reached by information campaign • Open digital science coverage • % of people who feel informed about nanotechnologies	• Better informed society with ability to claim demands
Promote public engagement activities in NMP	• Public influence on research agendas • No. of public engagement events (consultations, debates, etc.) • % of research projects which include public engagement activities • No. of citizen science projects	• Creation of trust • Greater transparency

10 Conclusions

In conclusion we want to summarize milestones, which stimulate in the short, medium and longer term research, development and innovation of nanotechnologies and nanomaterials in Latin America. The presented milestones are not the result of a foresight study, meaning that we do not intend to predict the future. Rather, we compiled recommendations, which resulted from our 2-year multi-stakeholder research process where we addressed the question of how nanotechnology-based solutions to societal challenges in the areas of health, water and energy should be produced in the future. Long term developments shall eventually flow into the achievement of the Sustainable Development Goals. As key actors for the implementation of the milestones we address in table 1 policy makers and in table 2 researchers and industry. Nevertheless, as we stressed repeatedly in the roadmap, we plead for an integration of all stakeholder groups in strategic decisions along the process of nanotechnology maturation.

It is important that the implementation of the roadmap or of individual milestones is accompanied by an evaluation of the research and policy progress and by a revision of the strategy. In the roadmap we give extensive options of indicators, which may help to decide on key indicators for the monitoring process.

More detailed recommendations for next steps for each topic may be found in thematic factsheets, which can be accessed through the website www.nmp-dela.eu.

table 1, milestones in policy making

Topic	Short term (by 2020)	Medium term (2020-2025)	Long term (2025-2030)
Funding	Launch of EU-LA joint calls on NMP priorities (translational nanomedicine, nanomedicine for tropical diseases, arsenic removal from mining and groundwater, public-private initiatives for solar energy applications)	Integration of more mature NMP public and private EU-LA cooperation into investment strategies of WB, IMF and other thematic investors	Significant increase in public spending for NMP
Education	Policy makers in LA (with support of EU and NanoAndes) introduce a monitoring system for nanoeducation	Introduction of monitoring system to assess the impact of mobility schemes for researchers on socio-economic developments in home countries	
Education	Increased investment in good quality nanoeducation in universities / vocational training schools (including mobility schemes)	Significant increase in No. of NMP researchers	LA meets the demand for nanotechnology specialists
Outreach	WHO Healthy Workplace Programme's guidelines on nanomaterials and workers' health are disseminated to relevant authorities and general public	Outreach activities and NanoDYF platform are integrated in government policies and funding strategies	

Technology Transfer	Introduction of monitoring system to evaluate cases of successful technology transfer and local expertise	Increased capacity for technology transfer and nanoinnovation	Upgrade of the technological capabilities of the industrial sector, in particular in developing countries (Sustainable Development Goal 9.5)
RRI	Use work of the Argentinean Ethics Board CECTE on a code of conduct for nanotechnology research as starting point to develop LA RRI vision	Established monitoring system to assess adoption of RRI standards in nanotechnology	
RRI	LA governments adopt UNITAR guidance for the development of a nanotechnology policy and programme	LA governments establish national working parties on occupational health and safety issues of nanomaterials.	LA governments are actively engaged in creation of international safety norms and regulation
RRI	LA uses toolkit developed by the RRI-tools project to develop own nano specific tools	Introduction of occupational health and safety guidelines for nanomaterials.	Introduction of independent supervisory authority to ensure compliance of safety standards
Cooperation	EU-CELAC Summit integrates NMP (plus target and performance indicators for NMP) in updated action plan	EU invites additional LA countries to join NANoREG according to their needs	

table 2, milestones in research and industry

Topic	Short term (by 2020)	Medium term (2020-2025)	Long term (2025-2030)
Health	Well established Latin American Nanomedicine Platform with mirror organizations in all LA countries	Significant LA research community in nanomedicine	
Health	Strong cooperation between industry/governmental bodies and scientific community to foster translational nanomedicine		
Health	Affiliation with patients associations, medical professionals and SSH researchers for need-driven solutions.	Fast and cheap point-of-care diagnostics are available for communicable diseases (e.g. tuberculosis)	Nanodrug delivery systems contribute to solutions for neglected tropical diseases through encapsulating toxic drugs

Water	Establishment of the Colombian NanoSENS lab-on-a-smartphone network for water quality monitoring	Some nanotechnology solutions for water desalination and waste water purification are scaled up to pilot and industrial scale	Development of mutually beneficial adaptation strategies and operating standards enabled through cooperation between companies, local governments and communities
Water and energy	Establishment of EU-LA-Africa Baleware platform for oversight / coordination of innovative projects		Growing concern for the environment and the protection and sustainable management of water
Safety	LA researchers engage more actively in SETAC, IWA, GWRC and the European Nanosafety Cluster	LA researchers contribute to strategic research agenda of the European Nanosafety Cluster	
Safety	Formulation of a white paper on nanosafety in LA	Establishment of a LA Nanosafety Cluster linked to the European one	
Energy	Brazil's investment in solar PV for energy production opens opportunities for cooperation with European researchers and industry.	Considerable cost reduction for solar energy equipment	

The main findings of the roadmap exercise are included in the summary at the beginning of this document, so readers are advised to read that part of the document as a reminder of the main lines in the roadmap and the recommendations. There appears to be interest on both sides of the Atlantic for explicitly including nanotechnology, new materials and production technologies in multilateral and bilateral governmental cooperation in science, technology and innovation as well as investment programmes on health, water and energy in LA. In addition, researchers and industrialists are interested in strengthening the Latin American presence in international research and innovation networks. This includes the supply side of nanotechnology, materials and production technologies as well as the application domains of health, water and energy. In particular, the Latin American wealth of minerals and biodiversity as well as specific issues, such as tropical diseases, lack of clean water and energy supply in remote regions could be interesting for European partners. Furthermore, recent European experience and insights in translational research and academia-industry cooperation as well as education and training, nanosafety and responsible research and innovation may be of interest to Latin American partners. This roadmap contains a plethora of ideas and suggestions that form a good basis for policy development as well as collaborative projects and networks. It is now in the hands of stakeholders to implement it.

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Annex 1: list of current funding opportunities for EU-Latin American cooperation in NMP

Public funds

The World Bank – INFODEV - www.infodev.org
"A global multi-donor program in the World Bank Group that supports growth-oriented entrepreneurs through creative and path-breaking venture enablers".

R&D&I

EU HORIZON 2020 - http://ec.europa.eu/programmes/horizon2020/en/
A wide range of research topics for R&D&I projects and individual grants.

EU LAIF (Latin American Investment Facility) -
http://ec.europa.eu/europeaid/regions/latin-america/laif-latin-america-investment-facility_en
A blending instrument mixing non-refundable grants from the EU and other donors and refundable loans of multilateral or bilateral public European Development Finance Institutions and Regional Latin American Banks. for investment in LA.

MERCOSUR FOCEM - http://www.mercosur.int/focem/
This fund for structural convergence of MERCOSUR invests in R&D&I in the Mercosur region in South America. Funding may include nanotechnology.

CYTED - http://www.cyted.org/
This IberoAmerican programme funds scientific networks and projects involving researchers from Spain, Portugal and LA. Thematic areas include agrofood, health, industrial development, sustainable development, climate change and ecosystems, information and communication technologies, science and society and energy. Several nanotechnology related projects have been funded so far.

BILAT (online database of EU bilateral R&D cooperation and funding) - http://www.bilat.eu/index.php
The database includes a list of funding opportunities searchable by country and research domain.
Bilateral programmes with Argentina (ABEST III), Brazil (B.BICE+), Chile (CEST+1) and Mexico (EU-MEX INNOVA) are included.

ERANET-LAC - http://www.eranet-lac.eu/

Network of the European Union, LA and the Caribbean Countries on Joint Innovation and Research Activities.

The Netherlands: Enterprise without Borders - www.ondernemenzondergrenzen.nl

This programme supports Dutch start-up entrepreneurs who want to set up companies in emerging economies and developing countries including in LA.

The Netherlands with Bolivia, Colombia, Guatemala, Nicaragua, Peru and Suriname. Dutch Good Growth Fund - http://english.rvo.nl/subsidies-programmes/dutch-good-growth-fund-dggf

This is a new revolving fund (since 1 July 2014) that support Dutch SMEs and entrepreneurs in 66 emerging economies and developing countries with refundable loans for investments contributing towards employment opportunities, expanding local production capacity and the transfer of knowledge in the developing country. The eligible countries include Bolivia, Colombia, Guatemala, Nicaragua, Peru and Suriname.

Match Making Facility (The Netherlands) - http://english.rvo.nl/subsidies-programmes/matchmaking-facility-mmf

This facility supports entrepreneurs from developing countries in finding Dutch counterparts for business partnerships. Eligible countries include Bolivia, Colombia, Guatemala, Nicaragua, Peru and Suriname.

Education and training

EURAXESS (Europe) - http://ec.europa.eu/euraxess/

General portal to research jobs and fellowships in Europe.

ERASMUS+ (EU DG Education) - http://ec.europa.eu/education/opportunities/higher-education/international-cooperation_en.htm

European higher education institutions and individuals can work with partner institutions outside the EU through international mobility, joint degrees, and international cooperation partnerships, including capacity building and staff development in emerging and developing parts of the world.

NUFFIC: Study in the Netherlands - www.nuffic.nl

NUFFIC is the portal for international students who want to study in the Netherlands and Dutch students who want to study abroad. It also facilitates international cooperation in higher education and support to the Dutch knowledge economy. They have support offices (NESO) in Brazil https://www.nesobrazil.org/ and Mexico (for all Spanish speaking Latin American countries): https://www.nesolatinoamerica.org/.

Private funds

Pew Charitable Trusts - www.pewtrusts.org

The Pew Latin American Fellows Programme in the Biomedical Sciences funds postdoctoral training of young Latin American scientists in the USA.

Wellcome Trust - www.wellcome.ac.uk

The Wellcome Trust International Strategy supports biomedical health research and training in lower and middle income countries worldwide. The focus is on

- public health research in communicable and non-communicable diseases and disorders, as well as health services research
- infectious diseases (including tropical and neglected infectious diseases, animal health, zoonoses and emerging infections).

Grants include fellowships and personal awards, current international initiatives and investigator awards.

Human Frontier Science Programme - http://www.hfsp.org/

This fund offers research grants and postdoctoral fellowships for research at the frontiers of life sciences. International cooperation between member countries of HFSP and other countries is stimulated as well as international mobility.

Bill and Melinda GATES foundation - http://www.gatesfoundation.org/

This fund targets inequities that are currently underfunded by setting its own strategy and direct solicitation of proposals by organizations that are well-suited to do the work. Occasionally they publish public requests for proposals on their website to broaden their network.

Annex 2: List of Projects Dealing with Ethical, Environmental and Social Aspects of NMPs

Project Acronym	Project Thema Description	Status
NANOPINION	European Platform on Nano Outreach and Dialogue (NODE)	Ended 10.2014
NANOEIS	Improving education in nanotechnologies to match the skill needs of EU industry and society	Ongoing
NANODIODE	Developing innovative outreach and dialogue on responsible nanotechnologies in EU civil society	Ongoing
STIMULATE	Advanced materials – our allies for a sustainable future	Ended 07.2015
NANOSOLUTIONS	Systematic investigations of the mechanisms and effects of engineered nanomaterial interactions with living systems and/or the environment	Ongoing
NANOVALID	Reference methods for managing the risk of engineered nano-particles	Ongoing
FUTURENANONEEDS	Development of a systematic framework for naming and assessing safety of the next generations of nanomaterials being developed for industrial applications	Ongoing
INSTANT	New methods for measuring, detection and identification of nanoparticles in products and/or in the environment	Ended 08.2015
SMART-NANO		Ongoing
NANODETECTOR		Ongoing
NANOTRANSKINETICS	Modelling toxicity behaviour of engineered nanoparticles	Ended 10.2014
PRENANOTOX		Ongoing
MEMBRANENANOPART		Ongoing
MOD-ENP-TOX		Ongoing
MODERN		Ongoing
NANOPUZZLES		Ongoing

Source: European Commission

Annex 3: Interviewees and participants in NMP-DeLA events

Interviews and survey health:

Prof Dr Marcelo Calderon, Department of Biology, Chemistry, Pharmacy / Institute of Chemistry and Biochemistry, Freie Universität Berlin, Germany http://www.bcp.fu-berlin.de/en/chemie/chemie/forschung/OrgChem/calderon/index.html

Dr Françoise Roure, CGEIET, Min Economie & Finances, France http://www.cgeiet.economie.gouv.fr/

Prof Dr Albert Duschl, Paris-Lodron University Salzburg, Austria, http://www.uni-salzburg.at/index.php?id=25707

Prof Dr Teresa Fernandes, Heriot-Watt University, UK, http://www.sls.hw.ac.uk/staff-directory/teresa-fernandes.htm

Dr Henry Andrade, Universidad Pontificia Bolivariana, Medellin, Colombia, http://www.upb.edu.co/portal/page?_pageid=1054,51984264&_dad=portal&_schema=PORTAL

Dr Miryam Asuncion, NanoGune, Spain, http://www.nanogune.eu/en

Dr Henri Heussen, ArboUnie / COSANTA BV, Netherlands, www.stoffenmanager.nl

Dr Gabriela Canziani, Ph.D, Fundación Instituto Leloir, Argentina, http://www.leloir.org.ar/

Dr William Waissmann, Fiocruz, Brazil, http://portal.fiocruz.br/

Dr Rossana Madrid, UNT (Univ. Tucuman) Bioengineering department, Argentina, http://www.unt.edu.ar/

Dr Mario Cisneros, Patent expert

Dr Luis Velasquez, CIMIS, UNAB, Chile, cimis.unab.cl

Professora Maria Espona, ARGIQ, Argentina, http://www.argiq.com.ar/

Prof Dr Alvaro Duarte Ruiz, UNAL, Colombia unal.edu.co

Interviews and survey water:

Prof Dr Dora Altbir, Director of CEDENNA, http://cedenna.cl/

Dr Rainer Christoph, Nanotecnia, UFG, UJMD, San Salvador, El Salvador, www.nanotecnia.net

Dr Susan Figueroa-Gerstenmaier, University Guanajuato, Mexico

Prof Dr Nidal Hilal, Director of the Centre for Water Advanced Technologies and Environmental Research (CWATER), Swansea University, UK http://www.swansea.ac.uk/staff/academic/engineering/hilalnidal/

Dr Luewton Lemos, , Centre of Expertise Water Technology CEW www.cew-leeuwarden.nl, 25-08-2014

Mr Santiago Nuñez, Director of Technological Development at the Ministry of Science, Technology and Telecommunication of Costa Rica
Dr Laure Peruchon, Brochier Technologies, France, www.brochiertechnologies.com
Prof Dr Bernabé Rivas, Vice President for research and development, Universidad de Concepción, Chile, http://www.udec.cl/
Dr María Angélica Rubio, Researcher at CEDENNA, http://cedenna.cl/
Dr Haico Te Kulve, University of Twente, Netherlands, www.utwente.nl
Prof Dr Annemarie van Wezel, KWR Water Cycle Institute, Nieuwegein, The Netherlands, http://www.kwrwater.nl/

Interviews and survey energy:
Prof Dr Paulo R. Bueno, UNESP, Brazil,
http://www.iq.unesp.br/#!/departamentos/fisico-quimica/docentes/paulo-bueno/
Dr Daniel Egbe, ANSOLE, Germany, www.ansole.org
Dr Susan Figueroa-Gerstenmaier, University Guanajuato, Mexico
Prof Dr Wim Sinke, ECN / NanoNextNL, Petten, The Netherlands
Mr Santiago Nuñez, Director of Technological Development at the Ministry of Science, Technology and Telecommunication of Costa Rica
Dr Felipe Pacheco, CEO ADROX, http://www.adrox.cl/
Dr Patricio Jarpa Bisquertt, CEO Nanotec SA, Chile, http://nanotecchile.com/
Representative Solliance, The Netherlands, Belgium, Germany, www.solliance.eu

Interviews and survey generic nanotechnology:
Dr Robert Baptist, CEA-LETI, Association Puya de Raimondi, France,
A representative of the Micro and Nanotechnology Research Institute CNM (CSIC), Barcelona, Spain: www.imb-cnm.csic.es
A representative of CNR IPCF, Italy, http://www.ipcf.cnr.it/

Participants in the NMP-DeLA workshop Nano for Health, 19-20 May 2014 www.nmp-dela.eu:
Prof Dr Eder Romero, Associacion Argentina de Nanomedicinas
Dr Ricardo Alvarado, Lanotec, Costa Rica
Prof Dr Alvaro Duarte Ruiz, UNAL, Colombia unal.edu.co
Prof Dr Juan Claudio Benech, MEC / IIBCE, Uruguay www.iibce.edu.uy
Dr Pedro Cazes / Dr Marcelo Kaniuki, LATINER, Argentina
Dr Carla Silva, CENTI, PT www.centi.pt
Dr Richard Anthony, KIT, NL, www.kit.nl
Dr Paula Queipo Rodriguez, PRODINTEC, Spain, www.prodintec.es
Dr Helvecio Rocha FIOCRUZ, Brazil, http://portal.fiocruz.br/

Dr Monica Silenzi, MINCYT, AR
Dr Santiago Sacerdote, CONICET, AR
Dr Daniel Lupi, FAN, AR
Dr Carlos Renaldi, CNEA, AR
Dr Hector Pralong, MINCYT, AR

Participants in the NMP-DeLA workshops covering Nano for Water (Monterrey, Mexico, November 2014 and Curitiba, Brazil, May 2015:

Dr Maria Teresa Alarcón Herrera (CIMAV, Mexico)
Prof Dr Damiá Barcelo, Vice Director CSIC Institute of Environmental Assessment and Water Research, (IDAEA), Barcelona, Spain, http://www.idaea.csic.es/
Prof Dr Jorge Gardea Torresdey, University of Texas at El Paso, USA, http://www.ssslogic.com/gardea/
Prof. Dr. Alejandra Martín Domínguez, Subcoordinación de Potabilización, Coordinación de Calidad del Agua, Instituto Mexicano de Tecnología del Agua, Jiutepec, Mor. México, https://www.imta.gob.mx/
Mr Carlos Fernando Mayo Gonzalez, Subsecretary of support to micro, small and medium enterprises, Secretariat for Economic Development and Tourism, State of Tabasco, http://sdet.tabasco.gob.mx/
Dr Miquel Rovira, CTM, Barcelona, Spain
Dr David Smith, WE&B, Mexico, Spain
Ms Lesley Tobin, Nanosafety Cluster, www.nanosafetycluster.eu
Dr Andrea de Vizcaya Ruiz, CINVESTAV, Mexico
MEI Leonardo Souza, Nodus Technology Transfer Office, Mexico, www.nodus.org.mx
Jan Hofman, Water Innovation and Research Centre University of Bath, United Kingdom
Dr. Daniel Martire - Universidad Nacional de La Plata, Argentina
Dr. Koiti Araki, Universidade de São Paulo, Brazil.
Dr. Juan Martin Rodríguez, Universidad Nacional de Ingeniería, Perú.
Dr. Bernabé Rivas Quiroz, Universidad de Concepción, Chile.
Dr. Eduardo Miró - Universidad Nacional del Litoral, Argentina
Dr. Jorge Rubio, MsC Ramiro Gonçalves Etchepare, Msc. André Camargo, Universidade Federal do Rio Grande do Sul, Brazil.
Dr. Edgar González, Pontificia Universidad Javeriana, Colombia.
Dra. Ma. Teresa Alarcón Herrera, Centro de Investigación en Materiales Avanzados, México

Participants in the NMP-DeLA workshop onNano for Industry, December 2014, Santiago de Chile and participants discussing general issues in other events:

Dr Marcela Anguro, CORFO, Chile
Prof Dr Dora Altbir, director CEDENNA, Chile
Dr Françoise Roure, French Government Ministry Economy and Finance / OECD WPN
Dr Patricio Jarpa, Nanotec SA, Chile

Dr Josep Lluis Checa, CEN LEITAT, Centre of Excellence in Nanofibers, Chile.

Dr Felipe Pacheco, Adrox, Chile

Dr Santiago Botasini, UdelaR, Uruguay

Dr. Edilson Silveira, Vice Chancellor for Research and Graduate Programs, Federal University of Paraná (UFPR)

Dra. Graciela Inez Bolzon de Muniz, Nanotechnology Central Laboratory (LCNano), UFPR

Dra. Noela Invernizzi. Latin American Network Nanotechnology and Society (RELANS), Public Policy Graduate Program, UFPR

Dr. Guillermo Foladori, ReLANS, Universidad Autónoma de Zacatecas, Mexico.

Mg. Ilse Marschalek - Center for Social Innovation, Austria

Dr. Alfredo de Souza Mendes. Coordination for Micro and Nano Technologies. Ministry of Science, Technology and Innovation, Brazil.

Dr Anna Tempesta, Coordination for Micro and Nanotechnologies, MCTI, Brazil

Ivana Resnichenko (MIEM, Uruguay)

Nico Schiettekatte, Innovation Council, Dutch consulate in Sao Paulo, Brazil

Participants in the NMP-DeLA workshops covering Nano for Energy (Monterrey, Mexico, November 2014 and Curitiba, Brazil, May 2015

Prof Dr Bob Chang, Department of Materials Science and Engineering, and Argonne-Northwestern Solar Energy Research (ANSER) Center, Northwestern University, USA

Dr Liliana Licea Jimenez (CIMAV, Monterrey, Mexico)

Prof Dr Miguel José Yacamán (Univ of Texas at Austin, USA)

Dr Bertrand Fillon, Laboratory for Innovation in New Energy Technologies and Nanomaterials, CEA, France

Prof Dr Wim Sinke, Energy Research Center Netherlands and University of Amsterdam , The Netherlands

Dra. Lucimara Stolz Roman, Universidade Federal do Paraná, Brazil.

Dr. Ricardo Faccio, Universidad de la República, Uruguay.

Dr. Pedro Migoski da Silva, Pontifícia Universidade Católica do Rio Grande do Sul, Brazil.

Dra. Andreia Gerniski Macedo, Universidade Tecnológica Federal do Paraná, Brasil.

Dr. Daniel Egbe – University Linz and ANSOLE, Austria