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Technology Transfer in Nanotechnology

Jacqueline E M Allan

Edited by:

Annarita Ferreri
Sergio Grande
Roberto Giannantonio
Francesco Matteucci

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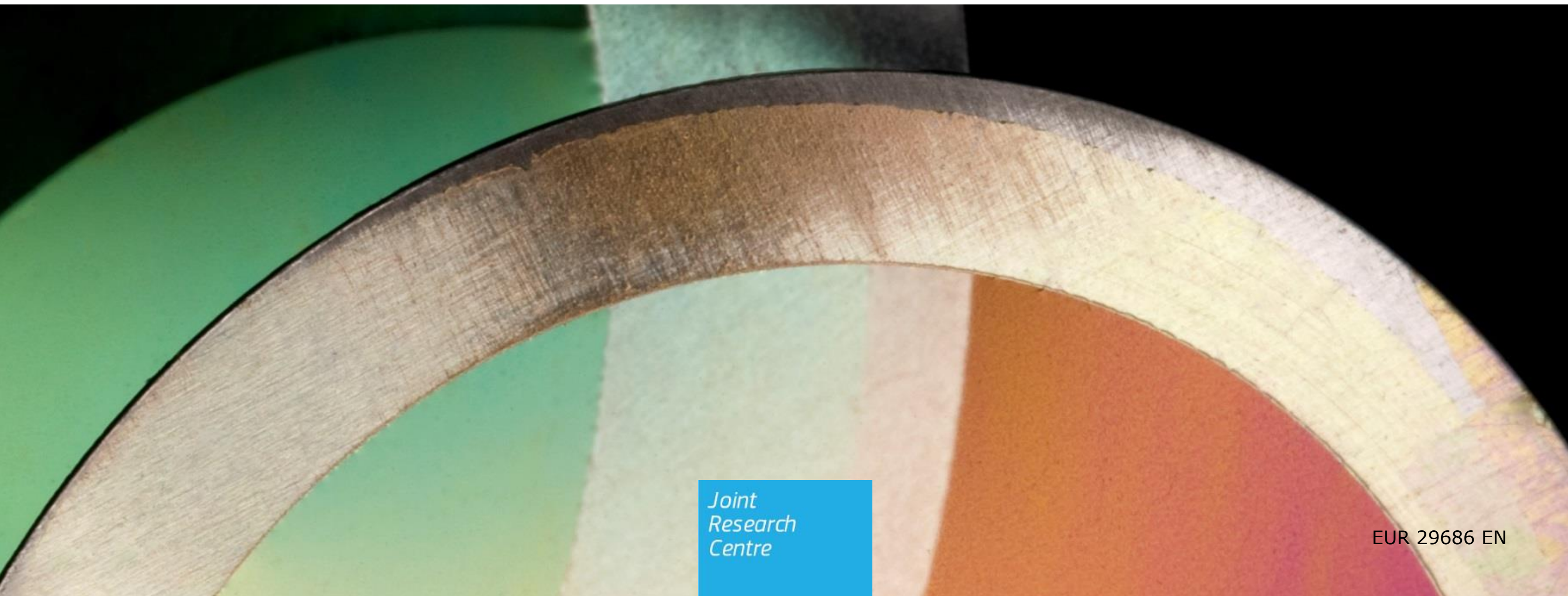

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FOREWORD

The Joint Research Centre (JRC) in collaboration with the Italian National Research Council (CNR) organized a workshop on **Technology Transfer in Nanotechnology,** which took place in CNR Nanotec on 18th and 19th October 2018 in Lecce (Italy). This workshop was organized in the framework of the TTO-CIRCLE initiatives.

The aim of this event was to explore how technology transfer activities can be used as a mechanism to help EU industry, particularly Start-ups and SMEs, in deploying and adopting Nano-technology. Practical examples were presented to illustrate the potential of technology transfer in this area.

The workshop gathered technology providers, industry executives, technology transfer officers, policy makers and financial intermediaries to share experiences and lessons learned. One of the key objectives was to discuss policy implications at all levels that could help accelerating the adoption of Nanotechnology by the European manufacturing industry.

About 120 participants attended this event. Representatives from JRC, DG RTD, European Investment Bank, Italian ministries, large industries, start-ups, technology transfer offices, and academics participated to this event.

Authors:

Jacqueline E M Allan[1], rapporteur

Edited by Annarita Ferreri[2], Sergio Grande[3], Roberto Giannantonio[4] and Francesco Matteucci[5]

[1] Joint Institute for Innovation Policy, Brussels
[2] European Commission, Joint Research Centre
[3] European Commission, Joint Research Centre
[4] DHITECH S.c.a.r.l
[5] DHITECH S.c.a.r.l

EXECUTIVE SUMMARY

Technology transfer is an essential part of the value chain that brings research closer to the marketplace. The technology transfer ecosystem is broad, involving researchers, entrepreneurs, industries, technology transfer specialists, investors and others.

For most academic researchers, technology transfer is largely the step of translating their research into a patent, or founding a company or seeking to establish a collaboration with industry. For RTOs (research and technology organisations), it is generally further along the value chain towards the market-place and involves patents, licensing and return-on-investment (in order to fund the ongoing activities of the RTO). For SMEs, it is often about finding the means to use their intellectual property to build their company towards profitability. For larger companies, including multinational enterprises (MNEs), technology transfer can take the form of collaborative projects, but more often it is about acquisitions and using patented or licensed knowledge. It is essential that all stages and types of technology transfer are optimised so that Europe can capitalise fully on its economically-relevant knowledge generation.

Nanotechnology research, development and innovation (RDI) is part of a wider European knowledge capital but there are specific characteristics that make technology transfer in nanotechnology (hereafter "nanotechnology transfer") more complex and demanding than for many other technology areas. Nanotechnology (i.e. technology at the extremely small scale of less than one thousandth of the breadth of a typical human hair, a scale at which the classical laws of physics no longer apply) has been termed as a horizontal, transverse, cross-cutting, disruptive and emerging technology – and it is undoubtedly a pervasive key enabling technology that has a role in many areas of manufacturing and an increasing number of processes and products. One challenge of nanotechnology is that it is ubiquitous and therefore hard to isolate, except within the scientific environment, e.g. of scanning tunnelling microscopes that have, since the 1980s, enabled the manipulation of single atoms[6] [7] and facilitated advances in the applications of nanotechnology.

Nanotechnology is multidisciplinary across physics, chemistry, biology, engineering, electronics and photonics, materials science, medicine and other disciplines. Each of those disciplines has its own language and scientific methods, as well as its own gestation period for technology deployment in the market. For example, some developments in information and communications technologies (ICTs) can be commercialised within the space of months while those in nanotechnology make take up to, and over, ten years to come to fruition. While nanotechnology is not alone in this (another well-known example being biotechnology), it remains a significant challenge in technology transfer.

Through a workshop in October 2018[8], a review of previous reports and additional discussions with experts, specific issues in nanotechnology transfer have been identified and measures to address them proposed. A more favourable environment for nanotechnology transfer can be created, as a stronger ecosystem for nanotechnology research and innovation, leading to more success in the use of intellectual property, in the creation of start-ups, and in the use of nanotechnology by SMEs and other companies in Europe through actions including the following:

- Achieve a standardised and accepted definition of nanomaterials that can be used throughout the EU (at least) and recognised globally, to facilitate standards and regulations, for safety at work and for consumers, and to foster the commercial use of nanotechnology-based processes and products.
- Increase the use of standards to both stimulate the growth of nanotechnology markets and ensure the quality of nanotechnology products in the EU and for export.

[6] Binnig, G., Rohrer, H., Gerber, Ch. & Weibel, E. Appl. Phys. Lett. 40, 178–180 (1982)
[7] Binnig, G.; Rohrer, H. "Scanning tunnelling microscopy". IBM Journal of Research and Development 30 (4): 355–69, 1986.
8 EC JRC workshop on Technology Transfer in Nanotechnology, 18-19 October 2018, CNR Nanotec, Lecce, Italy

- Support the whole value chain of nanotechnology through public or private funds, identifying the gaps where public funds are needed and recognising that nanotechnology research takes more time to come to fruition than many other technologies, thus requiring long-term commitment.
- Foster good practices in nanotechnology transfer - in education and training, entrepreneurship, collaboration, communication and commercialisation.
- Accept reasonable failure without excessive penalty in all parts of the nanotechnology value chain but especially for nascent business ideas and entrepreneurs, and promoting actions that can support change of mindset.
- Identify and finance the most promising and highest potential innovations to enable them to achieve demonstration, pilot production, scale-up and full-scale deployment.
- Support hubs with a good understanding of the needs of the community, with a portfolio of services to drive forward nascent nanotechnology industry, that can further support nanotechnology-related entrepreneurship through networking, mentoring and skills development. Such support hubs in nanotechnology can be role models for other hubs.
- Use horizon-scanning for high-potential innovations in nanotechnology, at EU level, nationally and in research organisations, identifying potential entrepreneurs who need support to bring their ideas forward.
- Broaden education and training to increase both entrepreneurship and the number of people having complementary technological and business expertise in roles such as nanotechnology transfer managers and patent lawyers.
- Require recipients of funding for early-stage commercialisation, and those aiming to set up a business, to complete training in intellectual property and undergo commercial coaching.
- Develop and maintain research and technology infrastructure for nanotechnology that appropriately takes into consideration technology push and market pull, depending on the purpose of the infrastructure and user needs.
- Support pilot plants and demonstrators as paths to bring nanotechnology research across the Valley of Death towards marketability, particularly in challenging areas such as nanotechnology, linking such facilities where appropriate and increasing good practice activities in awareness and interactions between stakeholders.
- Support nanosafety and risk research, including encouraging better (interdisciplinary) communication.
- Encourage the translation of nanosafety research into regulatory tools via EU and international cooperation.
- Facilitate partnerships between large companies and SMEs, to strengthen the SMEs and make nanotechnology transfer attractive for large companies to invest in. Encourage larger companies to grow their relationship with SMEs in support of a stronger EU nanotechnology transfer environment.
- Provide balanced and accurate information on nanotechnology for all stakeholders according to their needs.
- Enhance communication between nanotechnology stakeholders, increasing awareness and promoting links between providers, funders, financiers, users (for a process or product) and consumers of nanotechnology.
- Publicise the strengths of the EU in nanotechnology as one means of enhancing nanotechnology transfer, placing greater value on the history of EU nanotechnology advances, thereby facilitating learning from past experiences.

1 INTRODUCTION

1.1 Background

This report considers how technology transfer in nanotechnology can be optimised, building on existing good practices and also learning from technology transfer of other technologies. It seeks to help researchers, technology managers, industry and policy-makers, by informing and guiding their technology transfer activities in nanotechnology.

It is generally accepted, but not well received, that Europe is less successful in converting its research output into marketable products than the US, historically, and now, increasingly, Asia. To address this, Europe needs to create the right environment for more of its technological output to become commercialised. This means having the right conditions locally, nationally and EU-wide to support development and deployment.

Challenges (or missions) are expected to receive about half of the anticipated EUR 100 billion funding for Horizon Europe[9] (the upcoming EU Framework Programme 2021-2027), under its Global Challenges and Industrial Competitiveness pillar[10]. These will draw on the most advanced technologies, both enabling and disruptive, with nanotechnology being among the most versatile of those, albeit that it is still a technology in development with relatively few large-scale applications. Advanced materials (many at the nanoscale) are expected to become increasingly important for society and for business. This report therefore focuses on nanotechnology and increasing the success of Europe in transferring nano from being science and technology to its enabling products and processes, from the laboratory to the market.

1.2 Technology transfer[11]

Technology transfer is part of the innovation process; it is neither linear nor predictable, being multi-actor and multi-stage. Technology transfer involves, *inter alia*, identifying and developing new technologies; protecting them with an appropriate intellectual property strategy, via patents and/or copyrights; and establishing development and commercialisation plans (e.g. licensing or company creation).[12] Formal mechanisms of technology transfer include training, education, funded collaborative research and technical services. Informal mechanisms include the many and varied informal exchanges that take place between researchers and those applying nanotechnology, and structured knowledge exchange via papers and events. The most prevalent means of technology transfer is via published literature, patents and presentations at events (conferences, workshops, webinars, etc.).

Technology transfer can mean different things to different participants in the process, with each engaging in part of the value chain from knowledge creation to commercialisation. For higher education and research institutions, technology transfer may be their goal once research and development is advanced, the aim being to obtain buy-in from a company (including funding) or to patent a technology. For a company, technology transfer often begins once research and development (R&D) and prototyping are complete and the technology is ready (e.g. via licensing) to enter production (commonly pilot-scale production before full-scale production). A schematic of some basic stages of technology development and commercialisation are shown below, with an indication of where the interests of these two groups typically lie (darker shading indicating the highest organisational relevance). The middle of the graphic is where the least interest is likely from both types of stakeholder.

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[9] https://ec.europa.eu/info/designing-next-research-and-innovation-framework-programme/what-shapes-next-framework-programme_en

[10] https://ec.europa.eu/commission/sites/beta-political/files/budget-may2018-research-innovation_en.pdf

[11] Adopted from the OECD Policy Platform (www.innovationpolicyplatform.org)

[12] See AUTM.net (Association of University Technology Managers)

In nanotechnology, this central portion (often termed “the Valley of Death”) is where many potential applications fail, the risk involved coming at too high a cost for either group.

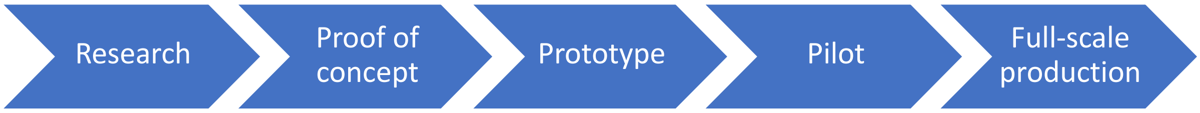

Figure 1: Schematic of some basic stages of technology development and commercialisation and the position of two main stakeholder groups

While many of the experiences in technology transfer in nanotechnology (nanotechnology transfer) have parallels in technology transfer in other domains, there are specific characteristics of nanotechnology that merit consideration in driving it towards commercialization, starting with the definition of the technology and its materials, as discussed below.

2 FACTORS AFFECTING NANOTECHNOLOGY TRANSFER

2.1 Nanotechnology and nanomaterials defined in the European Union context

The EU Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) has defined nanotechnology[13] as follows:

> *"Nanotechnology is the term given to those areas of science and engineering where phenomena that take place at dimensions in the nanometre scale are utilised in the design, characterisation, production and application of materials, structures, devices and systems. Although in the natural world there are many examples of structures that exist with nanometre dimensions (hereafter referred to as the nanoscale), including essential molecules within the human body and components of foods, and although many technologies have incidentally involved nanoscale structures for many years, it has only been in the last quarter of a century that it has been possible to actively and intentionally modify molecules and structures within this size range. It is this control at the nanometre scale that distinguishes nanotechnology from other areas of technology."*

In 2011, the European Commission put forward its non-binding *Recommendation on the Definition of a Nanomaterial (2011/696/EU)*[14] that states, in summary:

> *" 'Nanomaterial' means a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nanometre (nm) to 100 nm…. A material should be considered as (a nanomaterial) where the specific surface area by volume is greater than 60 m^2/cm^3." "…. fullerenes, graphene flakes and single wall carbon nanotubes with one or more external dimensions below 1nm should be considered as nanomaterials."*

Definitions are important: EU regulations adopted after the 2011 Definition (e.g. for biocidal products (528/2012)) use the above recommended definition but regulations adopted before the publication of the EC Recommendation 2011/696/EU use a different definition (e.g. for cosmetic products (1223/2009) and food additives (1333/2008)). Some key regulations are listed below by date:

- 2017: Medical devices regulation EU/2017/745
- 2015: Novel food regulation 2015/2283
- 2012: Biocidal products regulation 528/2012
- 2011: Plastic food contact materials regulation 10/2011
- 2011: Provision of food information to consumers regulation 1169/2011
- 2009: Cosmetic products regulation 1223/2009
- 2009: Active and intelligent food contact materials regulation 450/2009
- 2008: Food additives regulation 1333/2008
- 2006: REACH (chemicals) regulation 1907/2006

The Definition in the Recommendation (2011/696/EU) is an artificial (but useful) construct to assist in standardisation and regulation and has no meaning in scientific terms.[15] For example, the definition does not cover nanomaterials that do not contain nano-sized particles but that contain nano-sized holes (e.g. membranes), nor does it cover metamaterials[16]. However, definitions are usually a

[13] http://ec.europa.eu/health/scientific_committees/opinions_layman/en/nanotechnologies/about-nanotechnologies.htm#7
[14] http://ec.europa.eu/environment/chemicals/nanotech/faq/definition_en.htm
[15] Presentation (Technology Transfer in Nanotechnology Workshop, 18-19 October 2018, CNR Nanotec, Lecce, Italy) by Arnd Hoeveler, European Commission.
[16] http://www.iop.org/resources/topic/archive/metamaterials/

compromise as they need to be clear for users – to have clear manufacturing and safety guidelines, and to be able to market a product, or supply it to another company, for example. This will be covered also later in this document in the section on regulation and standards.

2.2 Nanotechnology in science and research

Nanotechnology is multi- and inter-disciplinary. Success in solving research and technology challenges often lies in collaboration between disciplines. This relies on communication, and on there being a clear value for stakeholder, and is at the core of Open Science and the goal of widespread dissemination of research results within the community.

Fundamental research is essential for the understanding of the human and material world but, of itself, is limited in its opportunities for technology transfer. Its focus is on the transfer of knowledge and expertise, through scientific journals, and student and staff mobility. Applied research, which may originate from fundamental research, is stronger in leading to technologies that can be transferred and commercialised. From the perspective of higher education and research institutions (HEIs and RIs), technology transfer is important, for example: in gaining recognition for new knowledge created; to attract corporate funding for research; as a source of income (e.g. via licenses); to comply with the terms of their public funding; to help local and national development; and to attract and retain talented staff.[17]

In order to achieve these goals, priorities for higher education and research institution research and technology managers include:

- A strong and innovative team of researchers doing world-class research;
- A continuous resource stream, from the laboratory to scale-up, for the long-term projects common in nanotechnology to avoid:
    - Developments being blocked for a time (or permanently) due to lack of money;
    - The loss of people (such as post-doctoral researchers) who are left with no prospects and no salary, and who take with them valuable know-how;
    - The lost time in training new people when funding becomes available, following the above loss of more experienced people;
- For the research managers to have view across all projects, to identify those that are most likely to succeed, and to be able to prioritise so that the highest-potential projects have enough resources to be successful (in terms of furthering knowledge and/or for commercial purposes);
- A dedicated technology transfer and support team in (or available to) their organisation;
- Strong and long-term public–private sector relationships (which may also provide additional research funding);
- The ability to bridge the gap between invention and the market, ensuring that
    - The product or invention is a viable proposition (e.g. can be upscaled, is patentable);
    - There is a market for it; and
    - A business can be created or established to bring it to commercialisation and being able to progress sufficiently far along the value chain and/or handover to others to commercialise;
- The finance to achieve nanotechnology transfer goals, often a long-term financial commitment.

There is a role for nanotechnology research and development organisations, such as universities and research and technology organisations (RTOs), in which nanotechnology research takes place to ensure that greater consideration is given to technology transfer and commercialisation. The root of this is that, in the applied context, technology is not a destination, but it can be a means to get to a

[17] See AUTM.net (Association of University Technology Managers). Additional material from Dr Corinne Monnier, CNRS Innovation, France.

destination. For researchers doing fundamental research, this not so important but for those doing applied research, there needs to be a discussion of the potential of the outputs of their work. For example, a researcher may develop a technology that appears to have a strong commercial potential. Their institution can and should foster a rigorous review of the materials or processes that are currently in place and whether innovation could be practical, cost-effective and acceptable. Some researchers work long and hard to develop a discovery but fail to transfer it or commercialise it because there is no customer or market for it, which is frustrating for them and not good use of public funding. Some sectors of industry are very traditional and hard to break into with nanotechnology, such as construction. Researchers need to consider this, and together with a technology transfer team, they should assess market appetite and determine the commercial and industrial benefit of that application upfront. If there is no evident market segment that could absorb that specific invention, it might be wiser to continue research activities at a fundamental level without raising any expectation of interest from industry. If the institutions can better characterise which research is fundamental and which is applied (and could be of commercial value), they will achieve better value for money.

From the perspective of an International Governmental Research Organisation (IGRO), in this case CERN, the decision to engage in collaboration is simpler. CERN produces technology to meet its own needs, not for industry. To facilitate this, sometimes it enters into a consortium with other organisations that have the same need (as was the case for the work that led to the Medipix collaborations[18]). This may, for example, be the need for a detector chip, which the partners in the consortium each want it for a different application and there is therefore a common goal and no conflict of interest. Subsequently, the consortium may license out the technology it has developed (e.g. in the Medipix case, to NASA for space dosimetry or to others for gamma cameras or 3D colour CT scanners). The key feature required for this to work is a collaboration agreement, an agreement that normally stipulates that all funders have rights proportionate to their contribution and that revenue should be shared according to a predefined scheme. Such CERN collaborations have also led to start-up companies based on detector technologies.

For nanotechnology, there are issues in particular around the vast range of nanomaterials that are in the process of research and development and that could be commercialised but may or may not become cost-effective products; achieving upscaling of materials from the laboratory scale to commercial quantities; and the reluctance of businesses to take a chance on nanotechnology (in funding research or committing to adoption of nanotechnology in their products or processes).

An ecosystem to accelerate the uptake of innovation in materials technology

The EU High Level Group on Nanosciences, Nanotechnologies and Advanced Materials reported in October 2017 on ways to improve the uptake of innovation in materials technology, including nanotechnology. It focused on four key areas for action – characterization, modelling, pilot production lines, and standards and certification. With specific policy relevance to nanotechnology transfer, the HLG recommended:

- To provide long-term support for research when applicable (ensuring continuation of research beyond the lifetime of individual projects) both via Horizon 2020 and national/regional funding;
- To increase awareness and promote links between technology providers, technology users (especially SMEs), consumers and funding providers;
- To encourage better (interdisciplinary) communication between material science and risk research;
- To support the development of standards materials characterization methods via EU funding;

[18] https://medipix.web.cern.ch

- To encourage the translation of safety research into regulatory tools via EU and international cooperation; and
- To support open access when applicable.

The report can be downloaded at https://publications.europa.eu/en/publication-detail/-/publication/96590d0c-b867-11e7-ac8e-01aa75ed71a1

2.3 Nanotechnology intellectual property

In nanotechnology, and other relatively new and enabling technologies, technology transfer from higher education institutions is limited, the majority retaining ownership of their intellectual property (IP). Although innovation is strong in nanotechnology, a number of factors contribute to a low number of applications reaching the market, for example:

- Researchers in nanotechnology may not be particularly motivated to seek to commercialise their ideas, preferring to publish. The path from that research to IP protection through patenting is often not appropriate, patents having the purpose of protecting solutions to technical problems, not to safeguard basic scientific results[19].
- Although university technology transfer offices are familiar with the mechanics of filing and managing intellectual property, their teams are often commercially inexperienced. Within academic institutions intellectual property is often filed for reputational, rather than commercial, reasons (also known as 'dark IP').
- It can be difficult to identify the true commercial potential of nanotechnology research and development (R&D), value that may be achieved later e.g. through licensing or a start-up. European researchers have less of a tradition of using their intellectual property for commercial purposes than in other countries, particularly the US. For example, in the recent EU NanoData study[20], it was seen that the US led for nanotechnology patenting in the period from 1993 to 2013[21] for the sectors of construction, energy, environment, health, ICT[22], manufacturing, photonics and transport[23], with Japan in second place in all except health (where it was Germany).
- Researchers who consider transferring their technology to industry often place an unrealistic value on knowledge that is fresh from the laboratory bench and only entering early-stage development. This can jeopardise their engagement with industry and damage potential relationships. It is critical in complex areas such as nanotechnology for the researcher and/or technology manager to know both the potential of their technology (technology push) and the needs of potential customers (market pull) and to have a strong plan to achieve (either themselves or through others) proof of concept, prototyping and pilot production so that the technology can, in due course, enter full production as a commercial product or process.
- In the past, there has been evidence of a 'land-grab' of intellectual property in nanotechnology, where countries or companies undertook preventive patenting in protecting materials without knowing what their future uses could be. Now that there is a better understanding of nanotechnology, there can be better early-stage reflection on the potential value of IP and whether or not to patent.

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[19] Korhonen and Simmelvuo at the Nanoforum workshop in Helsinki, 2007 https://www.nanowerk.com/nanotechnology/reports/reportpdf/report73.pdf

[20] NanoData study for EC DG-Research and Innovation under Framework Service Contract NMP4-FC-2013-ND0000, conducted by the Joint Institute for Innovation Policy (www.jiip.eu)

[21] Data used were for country of applicant. Source PATSTAT database, copyright European Patent Office (EPO)

[22] The greatest number of nanotechnology patent applications by sector in 1993-2013 was in ICT, both globally and for the EU and EFTA countries.

[23] These were the eight sectors considered in the NanoData study.

- Many in industry, particularly SMEs, do not have sufficient understanding of intellectual property and its exploitation and lack broader commercial skills. Unlike larger companies, SMEs also have no system of support for such business aspects.
- Nanotechnology projects tend to be long-term with a high level of expenditure before any turnover is achieved. For certain industries (e.g. transport, energy), products need to have a long lifetime before replacement is needed, making the proof of product stability and durability very important, also raising the length of time to market and the cost of commercialisation.
- Nanotechnology development requires both breadth and depth of knowledge without which it struggles to move forward to commercialisation. For example, in France, there is a lack of the SMEs to bring products forward sufficiently to engender the interest of large companies to manufacture on a large scale. For nanotechnology, most of the knowledge is either in small and highly-specialised firms or in very large ones that cover multiple domains, and there is often a missing part of the value chain that would link the one to the other. Sometimes this is achieved by acquisition or licensing but often the small company limps on and does not reach profitability. Medium-sized nanotechnology firms do not generally play the key role as translator of new knowledge between public research and industry.[24]

In terms of recommendations, the understanding of nanotechnology transfer by academic researchers at the start of their research careers could be greatly enhanced through a short period of training ("nano-IP 101") in intellectual property including patents, copyright, brands, trade secrets and trademarks, licensing agreements and non-disclosure agreements. This would help them to know when to patent, copyright or protect a trade secret and to avoid the loss of IP through ill-timed publication or other dissemination. It would increase the overall understanding in the research community and enable better nanotechnology transfer. Not all will want to use their knowledge output commercially (not should they) but those that are more business-oriented will have a greater chance of their ideas flourishing and reaching a market value via appropriate and well-timed nanotechnology transfer. Such training could be available for all researchers, professors, senior lecturers and grant co-ordinators in receipt of EC (or national) funding, every three to five years for repeat recipients of funding. There are already some examples of good practice (e.g. in short courses) that could be developed and implemented more widely in Europe.

Some EU schemes, such as the SME Instrument Phase 2 grant, insist on coaching for SMEs, in this case 12 days. SMEs that have experienced such coaching advocate making it a condition of receipt of any EU funding intended to support early-stage nanotechnology commercialisation. Similarly, such coaching would be of great benefit to academics and other researchers considering starting a business. Ideally, especially where the participants are from current or potential start-ups and SMEs, such training would have an international focus with participants benefiting from sharing their experiences to date and the problems they have had, in a mutual learning environment, as well as gaining a better understanding of international intellectual property systems. For more developed but still early-stage businesses, courses for advanced IP uses and IP negotiating skills would be beneficial. Continuing from there, as businesses become more advanced, courses could include: 'scaling an organisation', developing management systems for operational and commercial control/effectiveness; options for growing international sales; etc. the aim being to create a robust commercial pipeline in Europe based on nanotechnology R&D.

While there would be a cost involved in providing intellectual property/commercial skills courses (and effort to find sufficient mentors and business coaches), this would be offset by the increased probability of a successful nanotechnology business emerging.

It is noticeable that the majority of both technology transfer managers and patent lawyers, operating in (not only) nanotechnology, have backgrounds in the technology rather than in the commercial

[24] Corine Genet, Khalid Errabi, Caroline Gauthier. Which Model of Technology Transfer for Nanotechnology? A Comparison with Biotech and Microelectronics. Technovation, Elsevier, 2012, 32 (3-4), p. 205-215

world, which can be to the detriment of technology transfer. Complementary skills from technology and business are needed and the education and training system should foster those skills, and technology transfer offices make them a requirement among staff.

2.4 Entrepreneurship in nanotechnology

Entrepreneurship in the EU is low compared with other countries, with self-employment being seen as attractive by only about a third of Europeans compared to half of Americans and Chinese [25]. Failure is not well-received in Europe, as evidenced by a longer recovery time and likely reduced future investment following failure, relative to the US, for example. In Europe, public sector researchers often see no route by which to return to academia or a research organisation once they take time out to commercialise their invention or discovery. They are prevented from pursuing technology transfer because they fear that their departure will be permanent and are not willing to take that risk. Europe could better reward economic impact in applied science and enable researchers to move more freely between research and business environments during their careers.

The EU recently highlighted, in the context of the digital transformation and education [26], the need to boost entrepreneurial competences and an entrepreneurial mind-set for both new ventures and existing businesses in transformation. This requirement surely extends to all areas of transformative technologies and new materials, including nanotechnology, and can be enhanced by broadening education and training to stimulate and support entrepreneurship. Furthermore, entrepreneurs and those looking to start a business or licence out their technology need to be supported via training in intellectual property and commercial coaching. In particular, recipients of funding for early-stage commercialisation should be required to complete such training and coaching within the conditions of their funding.

One additional initial step is to identify potential entrepreneurs who need support to bring their ideas forward. Some academic institutions are proactive in this (e.g. the University of Manchester and its subsidiary Graphene Enabled Systems Ltd), creating environments to bridge the gap around demonstration and to reduce the risks for investors (see first box below). At EU level, in ICT, the European Commission has established an Innovation Radar to identify high-potential innovators and their innovations coming from EU publicly-funded research (see second box below).

Graphene Enabled Systems Ltd

Graphene Enabled Systems Ltd is a wholly-owned subsidiary of the University of Manchester, UK. Its mission is to create a series of successful graphene 'spin–out' businesses. The spin-outs license the University's portfolio of intellectual property (IP) in graphene and other two-dimensional materials but develop the IP for their own applications. To reduce risk for investors, it places high importance on high-quality product demonstrators, strong business plans (with a clear exit strategy for each spin-out) and early-stage management support. It takes no equity in the spin-outs.

Graphene Enabled Systems sees its role as bridging the gap between the university and industry, facilitating the move from lower to higher technology readiness levels (TRLs) [27], from research outputs at TRL1-3 to demonstrated technologies at TRL5-6 that are ready to make the transition to

[25] Only 37% of Europeans would like to be self-employed, compared to 51% of people in the US and China. https://ec.europa.eu/growth/smes/promoting-entrepreneurship_en

[26] https://ec.europa.eu/education/sites/education/files/digital-education-action-plan.pdf

[27] Technology Readiness Levels: 1 - basic principles; 2 - technology concepts; 3 - experimental proof of concept; 4 - technology validation in lab; 5 - technology validated in real environment; 6 – technology demonstrated in real environment; 7 – prototype demonstration in operational environment; 8 – system complete and qualified; and 9 – actual system proven in operational environment. http://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2016-2017/annexes/h2020-wp1617-annex-ga_en.pdf

industry. The team at Graphene Enabled has skills including technology evaluation; project engineering; market analysis and market engagement - many team members are sourced from industry. It also draws on experts to assess potential product ideas, retaining in the pipeline only those that merit further investment, with others being returned for further research to be undertaken; some licensed out directly; some kept for further consideration; and the rest rejected as unfeasible. The selected product ideas are supported through additional technical evaluation and market studies. In the following stage, ideas that are not rejected due to commercial, operational or technical issues progress to the demonstrator and business planning stages.

Spin-outs to date include**:**

- Atomic Mechanics - proprietary sensors, touch-interfaces and actuation devices based on graphene-polymer membranes - www.atomic-mechanics.com
- Gra-fine - high performance elastomers enhanced by nano-materials – www.gra-fine.com
- Graphene Water technologies - equipment and membranes to clean polluted water
- 'The Electronic Nose' spin-out, a chip based VOC sensor technology using functionalised graphene membranes.

For further information, see https://www.graphene-enabled.com

The EU (ICT) Innovation Radar

The Innovation Radar is an initiative of the European Commission focused on the identification of high-potential innovations, and the key innovators behind them, in FP7, CIP and Horizon 2020 projects in information and communications technologies (ICT). It supports innovators through a range of potential targeted actions to help them fulfil their potential in the market. It is an initiative that involves:

- Assessing the maturity of innovations developed within FP7, CIP and H2020 projects and identifying high potential innovators and innovations (using a model developed by JRC-IPTS);
- Providing guidance during the project duration in terms of the most appropriate steps to reach the market; and
- Supporting innovators through EU (and non-EU) funded entrepreneurship initiatives to cover specific needs in areas including networking, access to finance, and intellectual property issues.

The EU Innovation Radar covers all ICT research and/or innovation projects launched under Horizon 2020, FP7 and CIP supports, so innovators participating in any of these specific ICT projects can benefit. The potential innovations and/or innovators are identified with the help of external innovation experts and based on objective criteria discussed in the project reviews. Top innovators are promoted through the Digital Single Market webpages to increase their visibility with potential investors, users and buyers.

See https://ec.europa.eu/digital-single-market/en/innovation-radar

While education in science is about achieving at the highest level, entrepreneurship is about creativity and exploration of ideas. Entrepreneurs therefore need to be given the space to fail, as well as to succeed, which requires a change of mindset within the system. Approaches to entrepreneurship vary from one EU country to another, France being one of those that is promoting entrepreneurship from school age on, including at doctoral level.[28]

The role of small and medium-sized companies in nanotechnology is generally limited to the initial generation or adoption of nanotechnology e.g. in start-ups from universities or spin-offs from larger companies. The EU has over time been increasing support for an enterprise-focussed environment for nanotechnology and advanced materials: under Horizon 2020, for example, there is support for Open Access Pilot Line projects[29] in nanocomposites[30,31] and nanopharmaceuticals[32], and Open Innovation Test Beds[33]. Such initiatives could further support nanotechnology-related entrepreneurship through enhanced measures for networking, mentoring and skills development (technical and non-technical skills).[34]

EU Open Innovation Test Beds[35]

EU Open Innovation Test Beds offer access to physical facilities, capabilities and services required for the development, testing and upscaling of nanotechnology and advanced materials in industrial environments. The aim is to bring nanotechnologies and advanced materials within the reach of companies and users, to advance from validation in a laboratory (TRL4) to prototypes in industrial environments (TRL7). The Test Beds focus on testing and upscaling equipment, as well as modelling, characterisation, regulatory and technology advice, for innovative technology products that have already gone through the research process and are at ready for upscaling.

The funding under Horizon 2020 is to support the establishment of, or upgrading of existing, public and private test beds, pilot lines, and demonstrators. Private entities can apply for funding, as well as research and technology organisations, research centres or higher education establishments. The test beds are to be typically run by for-profit organisations with users coming from industry, including SMEs, innovators and start-ups. About 20 Open Innovation Test Beds are excepted to be created and EU support is being offered under Horizon 2020 NMBP calls scheduled in the following areas: lightweight nano-enabled multifunctional materials and components; safety testing of medical technologies for health; nano-enabled surfaces and membranes; bio-based nano-materials and solutions; functional materials for building envelopes; and nano-pharmaceuticals production, as well as materials characterisation and modelling.

Open Innovation Test Beds can help by providing a single entry point to facilities and services across Europe; reduce costs for both industry and users; offer harmonised conditions for testing, upscaling, characterisation and modelling; create faster maturation of products for faster market entry; give early-stage access to intelligence on EU regulations; and offer easier marketability of

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[28] In 2013, the French Parliament adopted the national principle that all children should acquire knowledge, skills and competencies to continue with further education, choose their own professional career and actively participate in civil life. In line with this, entrepreneurship is a cross-curricular objective in school education in France and is integrated in various optional subjects as well as being part of the compulsory subject Economic and Social Sciences during the last two years of education. This is continued in higher education with initiatives in French Doctoral Schools (e.g. MSc in Entrepreneurship at EDHEC Business School, Lille).

[29] For example, https://cordis.europa.eu/programme/rcn/665001_en.html, https://cordis.europa.eu/project/rcn/194436/factsheet/en, https://cordis.europa.eu/project/rcn/194436_en.html

[30] http://www.platform-project.eu; http://www.izadinano2industry.eu

[31] https://www.acciona-construccion.com/innovation/innovation-projects/materials/oasis/

[32] http://nanofacturing.eu/about/

[33] Open Innovation Test Beds are to be physical facilities, established in at least three Member States / Associated Countries, offering technology access and services to bring nanotechnology and advanced materials within the reach of companies and users in order to advance from validation in a laboratory (TRL4) to prototypes in industrial environments (TRL7).

[34] NanoData study for EC DG-Research and Innovation under Framework Service Contract NMP4-FC-2013-ND0000, conducted by the Joint Institute for Innovation Policy (www.jiip.eu)

[35] https://ec.europa.eu/jrc/sites/jrcsh/files/24012018-innovationweek-bowadt_en.pdf

products in Europe (e.g. non-European products to be tested in accordance to EU regulations to enter the market). OITB are expected to facilitate access of European SMEs along product supply chains.

Eligible costs under Horizon 2020 can include: acquisition, adaptation, installation and calibration of upscaling and testing equipment; demonstration cases; networking activities between Open Innovation Test Beds and similar initiatives; communication and dissemination activities; and design and development of services infrastructure: technology expertise; legal / regulatory expertise; modelling tasks; characterisation tasks; facilitation of access to funding for test bed customers.

After the end of EU funding, the Test Beds will have to operate autonomously using the revenues of the services they provide.

For further information, see http://www.nmpteam.eu/open-innovation-test-beds-guidelines/

PLATFORM – Open Access Pilot Lines, an example

PLATFORM is a research project funded under the H2020 Framework Programme to develop open access pilot lines for the industrial production of bucky-papers, carbon nanotube (CNT)-treated prepreg and CNT-doped non-woven veils for composite applications in sectors such as aerospace and automotive. The project builds on the success of two FP7 Framework Programme projects - ELECTRICAL and SARISTU – that developed methods to manufacture CNT-reinforced multifunctional composites compatible with industrial manufacturing processes.

The PLATFORM project core consists of 12 partner organisations (public and private) from six EU countries (ES, PL, BE, EL, IT and the UK) covering the entire value chain of the above product lines: nanomaterial supplier(s); experienced research and technology organisations (RTOs) with existing nanomaterial pilot plants (such as Tecnalia in Spain http://www.tecnalia.com, the coordinator of PLATFORM); and European composite material suppliers and end users from e.g. the aeronautical and automotive sectors.

The consortium comprises five RTOs, three large enterprises and four SMEs across the value chain for the development of the production facilities for new nano-enabled products. PLATFORM provides SMEs with open access to these facilities for direct product purchase, product development, collaborative research and training. The SMEs are also offered a wide range of supports ranging from nanocomposite development, production and integration and extensive testing facilities to support for business development and market exploitation.

The companies involved in PLATFORM are experienced in research and development and several have been involved in previous projects using EU funding. They include Adamant Composites (www.adamant-composites.gr); Carbures – an engineering and manufacturing company in composites structures, specialising in carbon fibre (www.carbures.com); and Nanocyl - a technology SME focused on nanocomposite product development (www.nanocyl.com). PLATFORM will automate steps in the manufacturing processes, introduce novel in-situ characterisation methods and incorporate instrumentation for nanomaterials and nanomaterials-based intermediates. The main goals are the higher quality of the products, improved process repeatability and yield whilst reducing lead times and product costs.

For further information, see http://www.platform-project.eu

Entrepreneurs need to know their technology and what it offers in technological terms (technology push) but also its potential market and the challenge the technology can solve for potential customers, i.e. the reason that a customer will want to buy it (market pull) and therefore the reason that a manufacturer will want to make it. A particular concern for nanotechnology is that entrepreneurs may engage in the application of nanotechnology without a full understanding of the technology, including potential risks and how they should be addressed.

2.5 Regulation and standards for nanomaterials

2.5.1 Legal aspects and Recommendations

Since 2007, nanomaterials must comply with the EU regulatory framework for chemical substances: REACH - the Registration, Evaluation, Authorisation and restriction of Chemicals in Europe. However, that regulation is not specific to nanotechnology or nanomaterials as that is not its purpose. Nanomaterials are covered by the definition of a "substance" in REACH, but there is no explicit reference to nanomaterials. In October 2017, the European Commission published its proposal, which is open for consultation and is to be implemented from 1 January 2020, to amend the REACH Annexes to address ‘nanoform substances’. [36]

In 2011, the European Commission made its Recommendation on the Definition of Nanomaterial (2011/696/EU) [37], which, in brief, states that:

“ ‘Nanomaterial’ means a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm - 100 nm…. A material should be considered as (a nanomaterial) where the specific surface area by volume is greater than 60 m^2/cm^3.” and “…. fullerenes, graphene flakes and single wall carbon nanotubes with one or more external dimensions below 1nm should be considered as nanomaterials.”

This non-binding Recommendation has been used since 2011 in regulatory situations that needed to define the term ‘nanomaterial’. Some are listed in the table below, together with regulations that pre-date the Recommendation and therefore use a different definition.

[36] https://echa.europa.eu/-/echa-welcomes-improved-clarity-on-nanomaterials-in-the-eu-member-states-vote-to-amend-reach-annexes

[37] Recommendation on the definition of a nanomaterial (2011/696/EU) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011H0696

Table 1: Overview[38] of selected EU regulations having relevance for nanomaterials (with X indicating where they contain a specific provision for nanomaterials), ordered by year (oldest first)

REGULATORY FRAMEWORK	Definition	Approval procedure	Safety assessment	Labelling	Guidance
REACH (chemicals) regulation 1907/2006[34]					X
Food additives regulation 1333/2008			X	X*	X
Cosmetic products regulation 1223/2009[35]	X	X	X	X	X
Active and intelligent food contact materials regulation 450/2009		X	X		
Plastic food contact materials regulation 10/2011		X	X		
Provision of food information to	X			X	

**Labelling of novel foods and food additives containing nanomaterials is required under the EU Regulation on the Provision of Food Information to Consumers 1169/2011.*

In the absence of an agreed definition of nanomaterials, the above being only an EU Recommendation, different definitions are currently in place across sectors and countries, not only the headline definitions but also the exemptions and thresholds that underpin their application for regulatory approval. This creates barriers to market access in terms of resources and skills needed to complete regulatory approval processes across sectors and territories. These barriers are particularly difficult for SMEs to overcome, both in knowledge and financial terms. For companies of all sizes, the added cost of diverse regulatory pathways will often exceed the cost-benefit threshold for market decisions.

At the international level, the International Organisation for Standardisation (ISO) is responsible for the standardisation of nanotechnologies with its TC 229. In Europe, the equivalent group is the European Committee for Standardisation committee on nanotechnology (CEN/TC 352) which has, for example, a working group on health safety and environmental aspects. While standardisation bodies have nanotechnology committees, nanotechnologies are also cross-sectoral and considered in other CEN and ISO working groups.

Standards are market driven and have a significant role in making nanotechnology more accessible to users, with the involvement of industry essential in developing and deploying relevant standards, but more needs to be done in facilitating the use of nanomaterials in manufacturing environments. Data sheets, handling advice and/or guidance on the use of materials in a real factory environment are urgently required by manufacturers. While issues around definitions need to be resolve d as a matter of urgency, it could be that interim measures and documentation that industry can use can be put in place until full resolution is achieved.

[38] Source: "Regulatory Aspects of Nanomaterials in the EU" by Rauscher H, Rasmussen K and Sokull-Kluettgen B, Chemie Ingenieur Technik 89, No. 3, 224–231 (2017), doi: 10.1002/cite.201600076. The information has been updated to reflect the coming into law of the Medical Devices Regulation EU/2017/745.

The EU Joint Initiative on Standardisation

The Joint Initiative on Standardisation aims to further drive innovation through working together (research, industry, standards authorities) for the most appropriate standards and to raise awareness of the importance of standards. It is undertaking fifteen Actions to modernise the European standardization system.

For example, the EU Joint Research Centre (JRC) is leading Action 2: *To establish a sustainable system that encourages the natural collaboration between researchers and innovators with the European Standardisation System, and allows for the smooth uptake of research and innovation outputs into standardization*

The three work-packages are to:

1 - Further develop and exploit Foresight Mechanisms - Putting Science into Standards initiative, bringing the scientific and standardisation communities closer together by anticipating and bringing new issues requiring standards to the standardisation community. So far, its work has included nanotechnology-related activities such as looking at quantum technologies and aiming to generate an overall quantum awareness among businesses and industry and to see where standards are most needed/relevant.

2 - Deepen Research – Standardization Integration - Foster and exploit the role of standardisation in Horizon Europe – including promoting market uptake of Horizon Europe projects outputs facilitated through standardization; promoting and disseminating best practice across innovation-related initiatives and networks to address standardisation as part of their Strategic Research Agendas; to coordinate the appropriate representation of professionals and researchers in standardisation activities; enhance the impact of pre- and co-normative research into R&I.

3 - Introduce standardization in the European Innovation Eco-system – Including to engage researchers and innovators via success stories, awards and illustrations of the benefits of standardization; and encourage industry research groups to include standardization in projects.

For further information, see http://ec.europa.eu/growth/content/joint-initiative-standardisation-responding-changing-marketplace-0_en

2.5.2 Research aspects

Support for regulation and standards comes from research into materials properties and their effects on the human and natural environment. While such research is useful, it is essential that resources be well used by minimising the duplication of effort. In addition, the outcomes of research need to have a purpose and a value. There are many risk studies of small groups of materials in specific situations (e.g. the health risks of carbon nanotubes should they become freely mobile in the environment) but life cycle assessments on nanotechnology are few, have restricted scope and make many assumptions. In the industrial environment, assessments are undertaken on pilot plants rather than full-scale industrial plants. There is therefore a lack of information from production to disposal or recycling. However, what businesses need is the best available information on which they can act in using nanomaterials. One approach would be to not wait for precise data on every nanomaterial in every situation but rather to implement the use of the materials with guidelines (at factory floor level) based on the best available information from the different sciences involved (physics, chemistry, toxicology, environmental sciences, engineering, biology, etc.). The challenge in this is recognised - there being the basic problems that the sciences do not speak the same language but also that business does not know what to communicate to other businesses or to customers - but it would enable industry to have a better environment in which to work, given that it is already using nanomaterials and has been for decades.

The NanoData study[39] highlighted that it is forecast that a very large number of new and modified nanomaterials are likely to emerge in the next few years, mainly driven by bio-applications, as in the health sector, for example. It is forecast that funding (public or private) will not meet the growing need for research, characterisation and testing (including research on testing protocols and monitoring). In addition, there will be severe pressure on data collection and processing systems, with improvements needed to be able to cope with very high volumes of data, greater than can be managed currently using ICT. Streamlining of efforts needs to be ensured (including standardisation of data capture) and duplication avoided.

The view from the EU High Level Group on Nanosciences, Nanotechnologies and Advanced Materials[40] is also relevant here, namely to:

- Encourage the further translation of safety research into regulatory tools via European and international cooperation;
- Encourage the creation of new opportunities for a competitive edge in innovation and market expansion by safe-by-design approaches if relevant;
- Improve networking between safety centres;
- Encourage better communication between material science and risk research (following an interdisciplinary approach);
- Continue support for standardisation through funding at Horizon 2020 and national level.

2.6 Nanotechnology infrastructure and the creation of platforms, networks and hubs

Infrastructure is part of the commercial value chain of nanotechnology, which starts at the laboratory bench and results in a product or process being on the market. In general, two different types of infrastructures can be identified depending on the TRLs (technology readiness levels) on which they focus – research infrastructure and technology infrastructure (see boxes below).

Research Infrastructures[41]: Facilities, resources and services that are used by the research community to conduct research and foster innovation in their fields (mainly TRLs from 1 to 4).

Examples of research infrastructures (RIs) include:

- Major scientific equipment (or sets of instruments);
- Collections, archives or scientific data; and
- E-infrastructures (data, computing systems, communication networks.

RIs are generally domain-specific, and can be single-site or distributed. RIs serve mainly researchers, both from academia and industry (including SMEs) and offer free access to facilities, technologies and services. Where relevant, they can be used for education or public services.

The European research infrastructure landscape comprises:

- Intergovernmental research infrastructure: well-established research infrastructure supported by the Member States and others (e.g. EMBL, CERN, ESA);
- New pan-European research infrastructure: research infrastructure listed in the ESFRI Roadmap (see box below); and
- Networks of national and regional research infrastructure open to all European researchers from both academia and industry. These networks of research infrastructure are promoted

[39] NanoData study for EC DG-Research and Innovation under Framework Service Contract NMP4-FC-2013-ND0000, conducted by the Joint Institute for Innovation Policy (www.jiip.eu)
[40] https://publications.europa.eu/en/publication-detail/-/publication/96590d0c-b867-11e7-ac8e-01aa75ed71a1
[41] https://ec.europa.eu/research/infrastructures/index.cfm?pg=home

by the European Commission through Integrating Activities for Advanced Communities (INFRAIA)[42].

Technology Infrastructures[43]: Facilities, equipment, capabilities and support services required to develop, test and upscale technology to advance from validation in a laboratory (TRL 4) to prototypes in industrial development (TRL 7), including:

- Pilot lines;
- Digital innovation hubs;
- Open innovation testbeds;
- KET centres (centres for key enabling technologies); and
- Demonstration sites of field labs.

Technology infrastructures (TIs) may be sector-specific or technology-focused and can vary in size and capacity, but they should adapt easily to changing industrial needs and fast technological developments.

They serve mainly companies, including SMEs, that seek support to develop and integrate innovative technologies towards commercialisation of new products, processes and services, whilst ensuring feasibility and regulatory compliance.

In considering any investment in infrastructure, particular attention must be paid to the parts of the value chain it is to address. If the aim is to facilitate research, multiple research instruments[44] [45] may be needed. If the aim is to enable technology transfer and commercialisation, a pilot plant[46] or process development facility may be seen as appropriate. The next step would be a demonstration plant, to be able to test the logistics, the advantages and possible drawbacks and challenges of larger-scale operations. In addition to their primary aims, some research infrastructures address education and training[47].

The European Strategy Forum on Research Infrastructures (ESFRI)

Since 2002, the European Strategy Forum on Research Infrastructures (ESFRI) has been supporting the development of EU research infrastructure. It develops strategic roadmaps, identifying the potential for new pan-European research infrastructures or major upgrades to existing ones, across sectors including energy, environment, health and food, physical sciences and engineering, social and cultural innovation, and digital. Research infrastructure on current or past roadmaps include solar telescopes, systems for scientific and heritage collections, synchrotron radiation facilities, advanced computing partnerships, e-infrastructure for biodiversity and ecosystem research, structural biology infrastructure, and global environmental,

[42] http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-infrastructures_en.pdf
[43] Link to the SWD on Technology Infrastructures
[44] See instruments from the EU Horizon 2020 Work Programme for Research Infrastructures (https://ec.europa.eu/programmes/horizon2020/en/h2020-section/research-infrastructures-including-e-infrastructures
[45] See JRC Research Infrastructures https://ec.europa.eu/jrc/en/research-facility/open-access/about
[46] http://ec.europa.eu/research/participants/data/ref/h2020/other/guides_for_applicants/h2020-supp-info-innotestbeds-18-20_en.pdf
[47] For example, see Renatech, the French network of high-end facilities in the field of micro & nanotechnology coordinated by CNRS. https://www.renatech.org/en/qui-sommes-nous/

seafloor and European plate observatories.

The mission of ESFRI is to support a coherent and strategy-led approach to policy-making on research infrastructures in Europe, and to facilitate multilateral initiatives leading to the better use and development of research infrastructures, at EU and international level. Delegates are nominated by the research ministers of the Member States and Associate Countries and work together to develop a joint RI vision and a common RI strategy to reduce fragmentation and waste of RI resources across Europe, aiming for the most up-to-date research infrastructures, responding to rapidly-evolving science frontiers, and advancing knowledge-based technologies and their use.

ESFRI is not a funding body: funding for research infrastructure comes at EU level currently, in large part, from H2020 under the Excellent Science pillar (EUR 2.4 billion from 2014-2020) and includes e-infrastructure.

For further information, see www.esfri.eu

Infrastructure can only enhance technology transfer if there is sufficient demand from potential users. There must also be the right infrastructure to meet all user needs, whether the research infrastructure is funded publicly or privately (or jointly). Any gap in the nanotechnology value chain will result in the technology not being commercialised. Therefore, full consideration needs to be given to the purpose of infrastructure from the aspects of both technology push and market pull, as with all other parts of the value chain.

Pilot production, through pilot plants and demonstrators, has been identified as a key vector in bringing research across the Valley of Death towards marketability, particularly in high-cost, high-risk areas such as nanotechnology and other key enabling technologies (see box below). Demonstrators are greatly under-rated: a good demonstrator is highly effective in raising money and winning business and must be designed not only to show the capability of the technology but also to demonstrate a viable pathway to manufacturability. The success of a demonstration plant or a flagship demonstration project can either (or both) test the workability of an innovation under operational conditions and drive the removal of institutional and social barriers standing in the way of an innovation (by promoting or aligning the discussion and development of policies and practices to enable the innovation to be commercialised and open its path to the market).

Pilot production

Crossing the Valley of Death requires a diverse set of (pilot production) activities linking technological development and the first commercialization of a product. These activities address the development of technologies (manufacturing and product oriented), as well as more organisational and market-oriented activities. This stage of the innovation process has a systemic nature and these multi-disciplinary activities show strong inter-linkages. Pilot production activities do not automatically lead to full production, this being especially true within SMEs.

The following activities are considered pilot production activities:

- Research and development to validate both technology/component/subsystem development in laboratory environment and "transferability" to pilot manufacturing;
- Set up of pre-commercial pilot manufacturing system operated by one or multiple industry partners, including participation of external bodies like SMEs and research organisations;
- Production of first pre-commercial products and prototypes for testing and validation of the product by customers and of the manufacturing process (including cost-efficiency);
- Adjusting product design based on pre-commercial manufacturing;
- Creation of market relationships with lead customers giving them access to new technologies, preparing the company for full commercialisation;

- Business development with internal and/or external investors; and
- Preparation of the internal and external organisation for full manufacturing, including the value chain development.

Pilot production, often termed 'pilot lines' and 'demonstrators', are crucial in the problems of crossing the Valley of Death. Pilot lines are pivotal in transforming the outcomes of technological research into competitive manufacturing, albeit that they are also capital intensive. Often policymakers are reluctant to support (high risk) pilot production facilities, regarding such investment as the responsibility of entrepreneurs or companies. But the economic risk is often too high for investors and companies, especially for SMEs and start-ups. [Nanotechnology] markets are still too uncertain and [the technologies] too complex to make the large investments needed to better understand and justify potential costs relative to revenues. Without public support, the consequence of such an impasse is that innovative nanotechnology solutions (for e.g. climate change, ageing and new jobs, and to address environmental challenges) will not reach the market. Society will therefore not benefit from the vast public investments in research and development up to lower TRLs if the investment to reach higher TRLs is missing. Indirectly, the innovation ecosystem and downstream industries will not benefit from the opportunities from [nanotechnology], weakening the economy at large.

Adapted from the Final Report of the mKETs-PL consortium (funded by the European Union), but including additional original material from this study/workshop

See: http://www.mkpl.eu/fileadmin/site/final/mKETs_D7_final_report.pdf

It is also essential:

- To avoid duplication of facilities and effort, particularly under the current budgetary constraints;
- To optimise the working of facilities through exchange of best practice, developing interoperability of facilities and resources and the training of the next generation researchers; and
- To encourage an appropriate and practical level of open access, for users from all sectors.

In its report of October 2017, the EU High Level Group on Nanosciences, Nanotechnologies and Advanced Materials made recommendations on pilot production lines (together with characterization, modelling, and standards and certification).[48] It particularly encouraged the promotion of the interconnection of pilot facilities and open innovation test beds (supporting open access); developing the system of test beds to cover the full range of value chain services (modelling, characterization, safety and business liaison services); increasing awareness and promoting links between technology providers (the pilots), users (SMEs), consumers and funding providers; and providing events about the use of pilot plants (for SMEs) and matchmaking/brokerage events and coaching at regional levels.

NFFA-EUROPE

NFFA-EUROPE – nanoscience foundries and fine analysis – is an open access research infrastructure for experimental and theoretical nanoscience funded under Horizon 2020 (Sept 2015 – Sept 2019). It is coordinated by CNR-IOM (Istituto Officina dei Materiali (IOM) of the Italian National Research Council (CNR)).

NFFA-EUROPE is a platform to facilitate multidisciplinary research at the nanoscale extending from synthesis and characterization to theory and numerical simulations. Advanced infrastructures,

[48] https://publications.europa.eu/en/publication-detail/-/publication/96590d0c-b867-11e7-ac8e-01aa75ed71a1

including synchrotron, free electron laser and neutron radiation sources, are integrated in a multi-site combination with state-of-the-art laboratories across twenty partners[49] for reproducible nanoscience research, to enable European and international researchers from diverse disciplines to carry out advanced projects impacting science and innovation. Half of the partners are nano-foundries that are co-located with analytical large-scale facilities.

Access to the facilities is through a Single Entry Point (SEP) portal with the assistance of the Technical Liaison Network (TLNet). NFFA-EUROPE offers transnational access, with 80% of access for EU Member States and Associated Countries, with support also for travel and subsistence. The results of the research have to be disseminated (except in the case of SMEs).

The technology transfer relationship between NFFA-EUROPE and industry is different from that between scientific institutions and companies. In accessing NFFA-EUROPE, companies ask the research infrastructures for solutions and the patents and prototypes created by the RIs are brokered to industry. In this way, they develop a type of shared goal, the RI to develop something new (e.g. to build an instrument) and the company to sell a new product (e.g. using that instrument in production). Industry uses the specific skills of RI-researchers (who routinely work with external users), access state-of-the-art, highly specialized instrumentation, have access to the RI for early stage basic research (often in cooperation with academic teams), engage with them in testing innovative developments, new protocols, and gain training and expertise.

For further information, see https://www.nffa.eu/about/

There is evidence that currently publicly-funded facilities are under-used while industry is looking for exactly those types of facilities but cannot access them due to State-aid rules, a situation that need to be revisited and revised.

Access to research infrastructure at the EC Joint Research Centre

The EC Joint Research Centre (JRC) hosts 37 physical research infrastructures with a potential of opening to external users (out of a total of 57 facilities). This it does while:

- Ensuring a fair and transparent method for allocating access;
- Bridging the gap between science and industry;
- Disseminating knowledge, education and training, fostering collaboration in Europe;
- Opening to EU Member States and countries with 'associate' engagement with Horizon 2020; and
- Providing capacity building to EU Enlargement and Integration Countries.

There are two modes of access, for relevance-driven access and market-driven access.

1. Potential research users for relevance-driven access apply following a call for proposals. There is a peer-reviewed selection process, taking into account scientific implementation, collaboration and access to new users, strategic relevance to the JRC and strategic importance for Europe. Access is mainly granted to universities and research institutions, public institutions, and SMEs, in association with industry. Users are only charged the additional costs (18% overheads) (free of charge for nuclear facilities). There is open access to data following an embargo period (typically 18 months), extended in case open access jeopardizes commercial exploitation.
2. For market-driven access, there is an agreement between the user and the JRC research infrastructure. Projects are selected by the JRC with an emphasis on strategic importance

[49] TUG (AT); DESY, Jülich, KIT and TUM (DE); FORTH (EL); ICN2, PRUAB and UPV/EHU (ES); CEA, CNRS and ESRF (FR); CNR, Promoscience and UMIL (IT); LU (SE); UNG (SI); STFC (UK); and EPFL and PSI (CH).

at EU level and on the uniqueness of the JRC facilities providing access. The access mainly targeted at industry and private institutions, as well as to, or in partnership with research institutions. Users are charged the full costs (70% overheads). Data is not disseminated via open schemes, but it can be used by the JRC for internal purposes.

The JRC has had for its Nanobiotechnology Lab: 22 eligible calls, 20 calls accepted, 5 completed projects, with 22 user institutions and 67 users.

In 2019, there is to be a revision of the access framework to:

- Allow the JRC to cover travel and accommodation of users accessing JRC Research Infrastructures, as well as to waive the additional costs of access in the relevance-driven mode.
- Possibly to include users from institutions from the RTD Spreading Excellence and Widening Participation list of countries.

From October 2018, there is also funding for training and capability building for H2020 associated countries, for people to visit the Nanobiotechnology Lab for a week with their travel and accommodation paid. This is for groups of users from universities, research or public institutions, or from SMEs, preferably with existing or under construction RIs similar to those of JRC. The Calls are under the JRC Enlargement and Integration Action.

For further information, see https://ec.europa.eu/info/departments/joint-research-centre_en

European researchers from the top laboratories are increasingly coordinating their efforts in shared platforms, particularly where the activities are far enough from the market-place for competition and intellectual property issues to be only minor. Some take a 'living lab' approach - user-centred, with a co-creation and open access attitude, and often funded through public-private partnership (see boxes below). In these, both technology push and market pull are present, with (business) ideas being proposed by (industry) partners, then reformulated and developed based on technology and taking account of the market.

Living Lab Approach: MINATEC Campus of CEA, France

MINATEC has adopted an approach to micro- and nanotechnology research based on the triple helix of higher education-research-industry. Its facilities are open to partners from academia as well as industry, the latter ranging from international companies to start-ups. The MINATEC innovation campus is home to 3,000 researchers, 1,200 students, and 600 business and technology transfer experts on a 20-hectare state-of-the-art campus with 13,000 m² of clean room space. It generates up to 350 patents and 1600 scientific articles every year and its synchrotron attracts researchers from many disciplines and from across the world. MINATEC has led to the creation of start-ups in micro- and nano-technology applications in fields including optronics, biotechnology, circuit design, and motion sensing. Fostering start-ups is seen as an efficient way to bring science and technology to society and to develop new industry. MINATEC has an annual operating budget of EUR 300 million, including EUR 50 million in capital expenditure. The Campus is intentionally ideally located as the local economy of Grenoble-Isère, in the heart of France's Rhône-Alpes region, is built around three major technology pillars: information and communication technologies, biotechnologies and new energy technologies.

For further information, see www.minatec.org

Living Lab Approach: Technological District DHITECH (Lecce, Italy)

The Apulian Nanotech Ecosystem (ANE) is comprised of research and technology organisations (RTOs) (e.g. CNR[50], University of Bari[51], IIT[52], ENEA[53], etc.), joint-labs amongst RTOs and firms (e.g. STMicroelectronics, Ospedale San Raffaele), SMEs and start-ups (e.g. TCT, MASMEC, Echolight, Biotec).

The Apulian District of High Technology (DHITECH) is a non-profit consortium embedding enterprises, universities and public and private research organisations. It acts as an Intermediary of Knowledge (IoK) organisation aimed at promoting and facilitating the development of ANE. It mainly acts through: i) training young researchers adopting a particular educational approach to stimulate their entrepreneurial attitude and develop their innovation mindset; ii) facilitating public-private collaborations between research centres – companies – financial institutions; and iii) communicating and disseminating the culture of Nanotechnology and innovation within schools.

For further information, see http://www.dhitech.it/progetti

Efforts are increasingly going into creating networks of infrastructure and hubs to support technology transfer and the translation of research into potential products. One such is grouped around nanomedicine research and the European Technology Platform for Nanomedicine (ETPN) (see box below).

The key attributes of that hub, as perceived by ETPN members are:

- A good understanding of the needs of the community;
- The provision of holistic and complementary services to drive forward an emerging industry; and
- A services portfolio that can seamlessly cover the most critical stages of development.

Support for Translation of Nanomedicines Research at the European Technology Platform for Nanomedicine (ETPN)[54]

The goals of the ETPN are to:

- Create conditions for successful translation of nanomedical advances;
- Help nanomedicine projects to develop faster;
- Increase the effectiveness of investment in Nanomedicine; and
- Improve the health of citizens worldwide.

To support the translation of nanomedicines research to the market, in 2015 the ETPN encouraged the submission of complementary proposals under the H2020 Framework Programme, the aim being to help grow the emerging industrial sector in nanomedicine. The success of the applications resulted in the Nanomedicine Translation Hub, with five European projects aligned with the Hub concept:

- ENATRANS[55]: to network and support SMEs in translation of nanomedicine in Europe, providing a one-stop-shop to interact and share information, experience and advice, also enabling personal contacts. Included is:

[50] Consiglio Nazionale delle Ricerche https://www.cnr.it
[51] https://www.uniba.it/english-version/university-of-bari-aldo-moro
[52] Istituto Italiano di Tecnologia https://www.iit.it
[53] Italian National Agency for New Technologies, Energy and Sustainable Economic Development http://www.enea.it/en
[54] Presentation (Technology Transfer in Nanotechnology Workshop, 18-19 October 2018, CNR Nanotec, Lecce, Italy) by Simon Baconnier, ETPN Safety and Characterisation Working Group https://etp-nanomedicine.eu/about-etpn/working-groups/wg-safety-and-characterization/ and EUNCL and CEA (FR)

- A Translation Advisory Board (nanomedTAB) with senior experienced translation experts to guide R&D teams (in start-ups, SMEs and research institutes) to firstly reach the clinical trials stage and later the market. nanomedTAB assesses the status and prospects of nanomedicine projects based on standardised criteria; provides feedback on business, strategic and technical aspects, makes recommendations to either continue, re-direct, re-start or discontinue projects; guides and mentors teams whose innovations are deemed to be more competitive to their next stage (e.g. technical development, funding, partnering, regulatory, manufacturing).

- EUNCL[56]: the European Nanomedicine Characterisation Laboratory, providing access to state-of-the-art, full characterisation (using the best available standards) of nanomaterials intended for medical applications, developed by public labs, spin –offs and SMEs.
- Three pilot lines for scale up of, and manufacturing services for, nanomaterials for medical applications:
  - NanoPilot[57], to build a GMP[58] pilot line for the production of polymer-based nanopharmaceuticals;
  - NanoFacturing[59], to scale up an existing GMP pilot line to a medium-scale sustainable manufacturing process for solid core nanopharmaceuticals (e.g. for clinical programmes on antiviral dengue fever nanopharmaceuticals) and to create a large-scale process platform for GMP compliant industrial manufacture, available as a model for other European companies wishing to develop their own products; and
  - MACIVIVA[60], an interdisciplinary consortium of established and innovative SMEs with scientific excellence and industrial world-leading experts with unique know-how in virosome technology, spray and freeze drying, large scale manufacturing and packaging.

The model of ETPN is ready to be replicated in other regions. The TAB is especially suited for regions with high proportions of early stage projects.

For further information, see https://etp-nanomedicine.eu

2.7 Funding for and investment in nanotechnology

Different technologies have different inherent timescales (e.g. a 6- to 12-month timescale for the development of some digital technologies versus the timescale for nanotechnologies and advanced materials that can be greater than ten years) and nanotechnology can be highly capital intensive, more than, for example, ICT. Nanotechnology research and development often requires highly specialised equipment, making it expensive to conduct. In addition, some of the commonly used nanomaterials are expensive e.g. gold. There is also a high rate of 'failure' of nanotechnology development, with researchers citing low reproducibility, making the area high-cost, high risk.

It is essential to have a continuous stream of support, whether public or private, to bring nanotechnology from the laboratory to the market. In development, each step costs more than the preceding one and the closer the technology comes to the market, the more has been invested in it and the higher the impact if it should then fail. There is the gap mentioned previously between the furthest point that a laboratory will typically go and the earliest point that a company will typically

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[55] https://www.enatrans.eu/public/nanomedicine-translation-hub#enatrans
[56] http://www.euncl.eu/
[57] http://www.nanopilot.eu
[58] GMP: good manufacturing practice
[59] http://nanofacturing.eu/
[60] http://www.maciviva.eu/

intervene. Some organisations are taking action to fill that gap (see the example earlier in this report of the University of Manchester / Graphene Enabled Systems Ltd) and there is also action at EU level for nanotechnology and other future and emerging technologies under the EU FET Innovation Launchpad programme of Horizon 2020 (see box below).

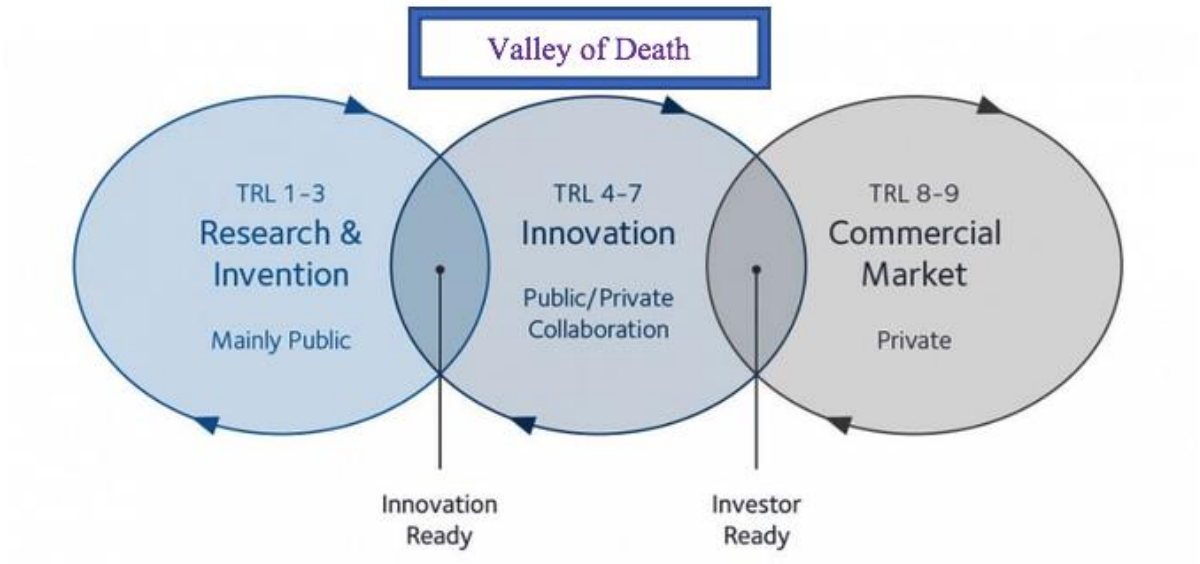
The FET Innovation Launchpad under Horizon 2020

The Future and Emerging Technologies (FET) Innovation Launchpad scheme aims to turn results from FET-funded projects (from FP7 or Horizon 2020) into genuine societal or economic innovations. The funded proposals are short individual or collaborative actions focused on the non-scientific aspects and the early stages of an innovation idea, stemming from ongoing or recently finished FET projects. The projects involve a wide range of actors, mostly from universities and research organisations, but also SMEs and industry partners, mostly start-up/ spin-off companies.

Nanoscience is mostly funded through public funding for the early stages of research and development (low TRLs and only up to TRL2 or TRL3[61]). If academic and research institutions bring research to TRL3 only, the incentive for industry to engage in the next stages – technology validation in the lab and in an actual environment – is low. Institutions could usefully demonstrate the potential of the technology in the real world by carrying it further along the development process, thereby making it more attractive to potential investors.

Nanotechnology is a key enabling technology (KET) and, as such, it can be seen as being a bridge between research and applications, between lower and higher TRLs. The figure[62] below shows the various stages of development grouped into three, with technology readiness levels (TRLs) and investor types (public, private). The Valley of Death (the point of no return after which many new ideas going through the innovation process fail to progress[63]) occurs between TRL levels 4 and 7.

Figure 2: The development of technology, from basic principles (TRL1) to commercial market (TRL8-9) (From uk-cpi.com, "The Innovation Challenge and the Valley of Death" May 2016) [64]



[61] http://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2016-2017/annexes/h2020-wp1617-annex-ga_en.pdf Technology Readiness Levels: 1 - basic principles; 2 - technology concepts; 3 - experimental proof of concept; 4 - technology validation in lab; 5 - technology validated in real environment; 6 – technology demonstrated in real environment; 7 – prototype demonstration in operational environment; 8 – system complete and qualified; and 9 – actual system proven in operational environment.

[62] Source: uk-cpi.com

[63] https://www.uk-cpi.com/blog/the-innovation-challenge-and-the-valley-of-death

[64] Adapted from uk-cpi.com, "The Innovation Challenge and the Valley of Death" May 2016

From an industry perspective, grant funding for further development of/beyond research often requires matching funding. This is difficult for companies in an area as uncertain as nanotechnology, particularly for SMEs, even for small sums. Money from institutions or government funding could bridge the gap to help bring technologies closer to transfer and commercialisation. While the aim of grants with matching funding is to share risk, they start at too early a TRL for nanotechnology and other higher risk (but potentially higher gain) technologies. Nanotechnology also attracts a low level of venture capital investment, particularly low in the EU, due to its aversion to risk. Overall, venture capital in the US is almost six times that in Europe, when the figures are normalized for GDP[65]. Europe may also be at a competitive disadvantage in this relative to Asia, where companies (and venture capitalists) are less risk-averse.

The role of nanotechnology SMEs is often limited to the initial generation or adoption of nanotechnology e.g. in start-ups from universities or spin-offs from larger companies, taking nanotechnology to the proof of concept stage (TRL3). They are much more rarely able to bring the nanotechnology to validation (TRL4-5) and demonstration (TRL6-7). In other areas, such as biotechnology, small companies can take a technology much further up the value chain, even to diffusion and deployment, which needs substantial capital (from the company itself or from external funds such as venture capital). Investors remain slow to support nanotechnology, seeing it as high-cost, high-risk with a long-term and uncertain return on investment.

Nanotechnology is a disruptive technology in many ways. As new developments come on stream, drastic changes are expected in manufacturing and these will require huge levels of investment. For example, electronics and ICT have reached the end of the range of Moore's Law[66] and the potential of silicon-based electronics. Changing to a non-silicon-based system will require manufacturing facilities to be renewed. This will have a large cost associated with it but, having reached the limits of silicon, there is no choice. It is more widely forecast that, in the (near) future new technologies will be used to produce new materials, ones that can be cheaper, more effective and more environmentally-friendly than those currently in use. There will be need for investments in courses aimed at developing innovation management skills for researchers (e.g. within doctoral training) and, in parallel, there should be a review of the way technology-based R&D and industry are financed, to better accommodate the higher risks that occur at the early stages of a period of radical change.

The COST Innovators Grant (proposal)

The European Cooperation in Science and Technology (COST) association provides funding for the creation of research networks, called COST Actions. These networks offer an open space for collaboration among scientists across Europe (and beyond), thereby giving impetus to research advances and innovation. Since 1971, COST has received EU funding to support such networks under the various research and innovation framework programmes, such as Horizon 2020.

COST is bottom up, so it is researchers in any field of science that, based on their own research interests and ideas, can apply to create a network via a proposal to a COST Open Call. It is also possible for them to join ongoing COST Actions, which therefore keep expanding over the funding period of four years. COST Actions are multi-stakeholder, often involving the private sector, policymakers and civil society. It complements the research and innovation funded through other grants.

COST is proposing to launch a COST Innovators Grant[67] under Horizon Europe (FP9) to enhance the pace and success of breakthrough innovations and to build bridges between the scientific research

[65] Source: Invest Europe / EDC and EVCA Eurostat (from presentation (Technology Transfer in Nanotechnology Workshop, 18-19 October 2018, CNR Nanotec, Lecce, Italy) by Alessandro Sannino of the University of Salento, Lecce (Italy) and Gelesis Inc., Boston, MA (US).

[66] See, for example, https://phys.org/news/2018-04-power-law.html

[67] https://www.cost.eu/wp-content/uploads/2018/08/COST_StrategicPlan_WEB.pdf

performed in COST Actions and marketable applications. An additional budget will be allocated to COST Actions that demonstrate commercial/innovation potential. The funding will cover the activities required to turn the research network outputs into either a commercial or technical proposition. The COST Innovators Grant will fund the networking, rather than the research/innovation activities themselves. In this, it ensures its complementary character in relation to other funding schemes, such as the ERC's Proof of Concept grant.

To fully benefit from the COST Innovators Grant and successfully implement it, COST Actions will also be able to apply for a one-year extension of their activities. The target is that at least 20 % of the completed Actions will be eligible for funding from the COST Innovators Grant from 2021 on.

For further information, see www.cost.eu

The European Investment Bank[68] is channelling support for innovation and competitiveness via a number of schemes in cooperation with other finance organisations and national bodies, for example:

- InnovFin[69], an EU Finance for Innovators initiative launched by the European Commission and the EIB Group in the framework of Horizon 2020. This consists of tailored financial instruments and an advisory service, covering both direct loans from the European Investment Bank Group (EIB Group), guarantees to and equity investment via financial intermediaries. More than EUR 24bn of financing for research and innovation by companies (of all sizes) is expected between 2014 and 2020.
- Nationally in Italy, for example, via the ITAtech investment platform dedicated to technology transfer. The aim is to stimulate the Italian innovation ecosystem, facilitating access to equity and investments for innovation throughout the entire business life cycle, from start-up and seed stages to growth and expansion, and to exploit intellectual property. Launched in December 2016 to transform research and technical-scientific innovations into new high-tech enterprises, ITAtech has an initial budget of EUR 200 million, in equal parts from the European Investment Fund (EIF)[70] and Cassa Depositi e Prestiti (CDP) (CDP)[71].

In addition, there are specific national initiatives to support high-tech companies, which, although not targeted specifically at nanotechnology start-ups, can have a positive effect (see box below, The Italian Start-up Act, 2012).

The Italian Start-up Act, 2012

The Italian policy framework for innovative start-ups (the "Start-up Act") was introduced in late 2012 (Decree-law 179). It aims to create a favourable environment for small innovative start-ups through a number of complementary instruments, including "fast-track" and zero cost incorporation, simplified insolvency procedures, tax incentives for equity investments, and a public guarantee scheme for bank credits. "Innovative start-ups" are defined as newly-founded (less than 5 years old) unlisted limited companies, with an annual turnover under EUR 5 m, and a focus on technological innovation as indicated by one or more of:

- Significant R&D expenditure (>15% of total annual costs)
- A highly-qualified team (one third being PhD students or graduates or researchers and/or two-thirds holding a Master's degree);
- Intellectual property (IP) rights (being the holder, depository or licensee of a patent or

[68] http://www.eib.org/en/
[69] http://www.eib.org/en/products/blending/innovfin/index.htm
[70] http://www.eif.org
[71] https://en.cdp.it

owner/author of registered software).

Companies that fulfil the requirements can (self-)register as innovative start-ups at their local Chamber of Commerce and benefit from support measures designed to help them throughout their whole life-cycle (first steps, growth, maturity) and to benefit the national start-up ecosystem as a whole (investors, incubators, universities…). The companies must be headquartered in Italy and have a mission statement explicitly related to innovation.

A large variety of data is collected on firm participants. The Italian Chambers of Commerce, on behalf of the Ministry of Economic Development (MISE), maintains a registry on the participating start-ups and conducted a detailed survey on ex-ante firm characteristics such as funding sources and employment composition.

An assessment (OECD, 2018)[72] has shown that companies that benefit from the policy, compared to a control sample, show:

- A 10-15% increase in turnover, value added, patent activity and investments in tangible and intangible assets;
- Increased likelihood of obtaining bank loans, often at a lower interest rate;
- A higher probability (more than double) of receiving venture capital in the first three years of the company;

Overall, since the launch of the policy, the popularity of the start-up phenomenon in Italy has measurably increased.

The OECD evaluation highlights that the impact of the policy on beneficiary firms has been positive overall, but that complementary policy actions in other areas are required in order to further realise the full potential of Italian innovative start-ups.

For further information, see: mise.gov.it; startup.registroimprese.it; italiastartupvisa.mise.gov.it

SMEs experience some specific challenges in being attractive to investors while retaining control of their intellectual property and their business. One example of a successful high-tech nanotechnology spin-out company with a focus on protecting intellectual property and supporting staff to understand its importance, is given in the box below (An SME view: Cellix Ltd.).

An SME view: Cellix Ltd. [73]

Cellix is a spin-out company that originated in work from Trinity College, University of Dublin, Ireland. Since it began as a company in 2006, it has developed its product range, based on research and development, in the areas of microfluidic pumps and biochips for cell-based assays. It sells to companies (including Allergan, AstraZeneca, Merck, and Pfizer) and to academic institutions and research bodies in Europe, the US and across the globe.

Cellix relies on know-how, copyright (software) and trade secrets as well as having a strong patent portfolio (six patent families with ten granted patents and 35 patent applications) across microfluidic pumps, biochips, cell-based assays; impedance and advanced electronics; and gene transfection assays / tools / techniques. Having recognised that the original research market it was targeting was quite niche and thus difficult to scale; Cellix re-pivoted its business, focusing on the development of innovative technologies, which form the foundation of its patent portfolio. Now, Cellix's revenue model is based on that IP and it operates via licensing, joint ventures and original equipment

[72] https://www.oecd-ilibrary.org/docserver/02ab0eb7-en.pdf?expires=1550488780&id=id&accname=guest&checksum=3AAD699E6C16CF04811C9EB0BFD3FADC

[73] Adapted from presentation (Technology Transfer in Nanotechnology Workshop, 18-19 October 2018, CNR Nanotec, Lecce, Italy) by Vivienne Williams

manufacturer (OEM) agreements.

Although Cellix began developing and selling tools into research laboratories, with its new business model, it has now diversified into food and beverages, agri-biotech and health and personalised medicine. Within these new fields, it is flourishing and has, amongst other things, developed a rapid diagnostic test for draught beer that is being tested by the top breweries worldwide (controlling 48% of the market) and beer-line cleaning companies.

Cellix monitors its knowledge creation and IP and insists on patent filing, where necessary, before any dissemination through workshops, conferences or other activities is allowed to take place. Cellix is currently developing its IP programme in-house, including ensuring that staff complete an invention disclosure form (IDF) and receive training in company IP requirements, structures and management.

Although not yet implemented and still under review, Cellix has identified schemes used by other companies to incentivise their staff to be mindful of IP and to protect it:

- EUR 100 / voucher / non-financial incentive for every new IDF filed with the technology transfer office;
- EUR X for each successful Search Report (i.e. report on any documents to be taken into consideration in deciding whether an invention is patentable or not); and
- EUR Y for each patent granted.

Cellix is also very aware of the potential value of IP and is further developing its strategy on how best to monetise IP in different situations. Their decision-making process is supported via market research (looking at the size of the market, the percentage of the market that is likely to be captured by the IP and whether the IP is better than what is already on the market (the unique selling point or USP)) and IP valuation models using costs (what has been invested so far), market (comparing with similar businesses/technology transactions as an upper limit to what and licensor will pay) and income (theoretical and based on revenue, profit and cash-flow estimates).

For further information on Cellix, see: https://www.wearecellix.com

2.8 Market adoption of nanotechnology

Nanotechnology has the potential to make a significant impact in areas including health, transport, energy and construction[74,75]. It can be an industry disruptor (e.g. in lighting, with the incremental developments from tungsten to halogen to fluorescent lighting but then a leap forward to gallium nitride light-emitting diodes (GaN LEDs) and organic LEDs). This gives it the power to create huge new markets and to foster the development of an industry (something that is particularly being sought in ICT now that the Moore's Law barrier has been reached).

Nanotechnology has been adopted in niche areas such as cancer treatments (to help target treatments to the cancerous cells using nanoparticles of gold) but areas in which it could reach high market volumes are currently closed to it due to the inherent cautious nature of the industry. For example, nanomaterials are being promoted for building insulation and other areas in construction, However, the construction industry is slow to adopt such innovations, also because the materials they use need to last for decades, even centuries, the length of time that buildings are expected to last, a timeframe for which nanomaterials are untested. This is just one example of market

[74] NanoData study for EC DG-Research and Innovation under Framework Service Contract NMP4-FC-2013-ND0000, conducted by the Joint Institute for Innovation Policy (www.jiip.eu)

[75] F. Matteucci, R. Giannantonio, F. Calabi, A. Agostiano, G. Gigli and M. Rossi, Deployment and exploitation of nanotechnology nanomaterials and nanomedicine, AIP Conference Proceedings 1990, 020001 (2018); https://doi.org/10.1063/1.5047755

reluctance to adopt nanotechnology, a challenge that impacts on the value chain right back to R&D. If a high-volume industry such as construction were to adopt nanotechnology, the costs of products (currently high) would drop due to scale and demand effects. Additional investment would be expected to follow, from the industry and external investors.

Another issue for market adoption relates to standards and regulations. If a material cannot be proved to be ‘safe’, a potential purchaser will be reluctant (or unable) to buy it. While many companies are making nanomaterials, they may find them hard to sell. This is related to the need for definitions, standards, product data sheets and guidelines for the use of nanomaterials mentioned previously.

Comparing with other high-tech areas, some studies[76] show that the nanotechnology transfer model is very different from that involved in biotechnology evolution: while small–medium firms play a valuable technology-bringing role, the central function of “translating” new knowledge between public research and industry is carried by the larger firms, just as it was in the early stages of the microelectronics sector. These results suggest that specific policy initiatives to facilitate biotechnology technology transfer are inappropriate to boost the diffusion of nanotechnology.

Many nanotechnology developments are too early stage for large companies. It is an uphill battle to interest them, although once they are convinced (perhaps by technology advocates with exciting demonstrators) they become evangelists themselves within their company or group. When they commit to the project, they will defend it within their organisation up to the highest levels. Advocates therefore play an important role in ‘selling’ nanotechnology to industry.

Companies can also work with each other to bring nanotechnology to the market as customer and supplier, optimising the speed to market through simplified engagement processes (see a company example in the box below: Beneq Oy). Matchmaking events and activities can be the first step to initiate such relationships.

Beneq Oy, Finland[77]

Beneq was established in May 2005 in Vantaa (Finland) as a management buy-out (MBO) spin-out from Nextrom (ex. Nokia-Maillefer). Its competence background (under Nextrom) came from the fibre optics industry. In 2012, Beneq acquired EL-display business (Finland) from Planar Inc. (US). The company employs 150 people including more than 10 PhDs, and has bases in Finland (headquarters), Germany, the USA and China. It has revenue of EUR 25 million, 97% outside of Finland (firstly, in APAC, secondly in the EU and thirdly in the US). It holds over 250 patents.

Beneq Oy designs and manufactures coating equipment based on nanotechnology. It is a leading supplier of production and research equipment for thin film atomic layer deposition (ALD) and aerosol coatings, as well as manufacturer of the thin film electroluminescent (TFEL) displays that are produced in its Lumineq sub-unit.

Beneq provides ALD development services and ALD coating services via a complete ALD service called “Thin as a Service”™. By working with customers it enables them to implement thin film coatings from coating chemistry research, through proof of concept to full-scale ALD production faster, more easily, with less risk and customised to their needs. To achieve this, Beneq places great importance on knowing its customer and their needs, co-creating and developing the product

[76] “Which model of technology transfer for nanotechnology? A comparison with biotech and microelectronics”, Corine Genet, Khalid Errabi, Caroline Gauthier, Technovation, Volume 32, Issues 3–4, March–April 2012, Pages 205-215 https://doi.org/10.1016/j.technovation.2011.10.007

[77] Adapted from presentation (Technology Transfer in Nanotechnology Workshop, 18-19 October 2018, CNR Nanotec, Lecce, Italy) by Jukka Nieminen, Beneq Oy, and from the case study on Beneq Oy in the NanoData study for EC DG-Research and Innovation under Framework Service Contract NMP4-FC-2013-ND0000, conducted by the Joint Institute for Innovation Policy (www.jiip.eu)

together with the client.

Beneq implements standard terms and conditions for the development service in preference to a joint development or similar agreement that could require lawyers and take more time. It has standard rules for foreground and background intellectual property with the client. The service process is streamlined, with clear responsibilities, well-documented so that the customer knows in advance what documents and deliverables they will receive. Beneq invoices in phases with a low entry level that is easy for the client to achieve. The application results are typically not patented, but protected as "trade secrets". The accelerated and trust-based process works well for Beneq (as a service and equipment supplier) and for customers, who see a reduced 'time-to-market' if the product is successful.

For further information, see: www.beneq.com

Too often, researchers and small companies approach large companies with novel solutions to problems, but these have no value if they do not match the actual problems of the large company. Some large companies have taken the step of listing on their website the problems that they are trying to solve (e.g. GE Healthcare, Millipore-Sigma, ThermoFisher)[78] and even problems that they are not trying to solve (e.g. GE Healthcare). It can be extremely time-consuming to contact all the companies that appear, from market research, to be relevant and it would be of significant benefit to smaller entities if large corporations could at least identify areas of interest on their website, if a list of desired technologies.

Initiatives to help build partnerships between companies include corporate match-making days and business acceleration services (business match events) (e.g. under the EU H2020 SME Instrument Phase 3). For these, the organizer (such as the European Commission) works with large corporates to organize match-making days between large companies and SMEs (or even academics, depending on the position of the event relative to the nanotechnology value chain and the types of solutions that the large companies are looking to find). The SMEs apply to participate, ensuring that there is a reasonable vetting of the companies prior to them taking part in the match-making event.

Partnerships between large companies and SMEs would help both to strengthen the SME and to bring the technology to the level where it has potential for the large company. Large companies can rapidly accelerate the time to market but many are cautious and slow to react, with short-term return on investment being an important consideration although this can disadvantage new opportunities. Partnerships between large and smaller companies need to be equal in terms of the value that each company places on the role and needs of the other. So far, there has been a reluctance to engage but this is being helped in part by partnership mechanisms including the EU Joint Undertakings[79]. Tax incentives could also be used to foster this part of the value chain.

[78] GE Healthcare:
https://www.gelifesciences.com/en/ee/business-partnerships/partnerships-and-licensing/in-licensing
Millipore-Sigma:
https://www.merckmillipore.com/IE/en/support/licensing/partner-with-us/Aq2b.qB.VPQAAAFAi0YQWTWr,nav?ReferrerURL=https%3A%2F%2Fwww.google.ie%2F&bd=1
https://www.merckmillipore.com/IE/en/support/licensing/Dept-of-Tech-Transfer/Kayb.qB.ZY4AAAFA2cAQWTWp,nav?ReferrerURL=https%3A%2F%2Fwww.google.ie%2F&bd=1
ThermoFisher:
https://www.thermofisher.com/ie/en/home/about-us/partnering-licensing/business-development-in-licensing.html
[79] For example, see https://bbi-europe.eu/about/about-bbi

2.9 Perception and awareness of nanotechnology

Nanotechnology has suffered both from over-hype and over-precaution. When it first emerged, it was oversold by many in order to obtain research funding. It was promoted as the solution to all possible challenges, from curing all cancers to meeting all our energy needs. While it may at some point achieve these goals, the process of translating technology from the theoretical to the actual is a slow and arduous one and there needs to be a realistic assessment of the distance travelled (and still to be travelled) along the development path. The initial hype has died down, in some cases being replaced with disillusionment when the promises were not delivered on. Nanotechnology has now been somewhat overtaken by the broader notion of future, key enabling and emerging technologies.

An accurate view is needed of the potential of nanotechnology for successful transfer to successive points on the value chain, coupled with an awareness of its potential risks and benefits. Communication is very important for nanotechnology because of its many facets. Nanomaterials can be used in many ways across many sectors and with many potential customers.

Education is very important in achieving public awareness without excessive concern or fear. Some good practices that are currently being used and could be developed elsewhere and given support include:

- Massive open online courses (MOOCs): For example, researchers at the University of Paris-Sud, Labex NanoSaclay and the University of Paris-Saclay have put on MOOCs lasting seven weeks in 2017 and 2018 on "Understanding Nanosciences". These are suitable for people with a technical background (such as a science diploma, BAC+2) rather than the broad general public.[80 81]
- The *Fondation de la Maison de la Chimie* (Paris Chemistry Foundation) is organising conferences on nanotechnology for a large audience.[82] Universities and research institutes (such as the CNRS) also organise science cafés and conferences for the general public .
- Some governments use web-based methods, amongst the best-known being https://www.nano.gov from the US National Nanotechnology Initiative (NNI). This provides a definition of nanotechnology, explains why standards matter, identifies infrastructure and list laboratories, teaching resources, events, etc. Under technology transfer it states that:

  > *"Although federally-funded R&D yields hard-to-quantify benefits such as students educated, degrees conferred, companies started, patents and copyrights granted, developmental partnerships formed, and private sector investment inflows, there are many indicators of the impact of this investment. For example, there (were) over 1,900 U.S.-based companies conducting R&D, manufacturing, or product sales in nanotechnology in 2016.... NNI agencies have developed an extensive infrastructure of nearly 100 major interdisciplinary research and education centres and user facilities across the United States. This cutting-edge fabrication and characterisation equipment provides state-of-the-art nanoscience tools and expertise for research by non-profit or business organizations, whether small or large, for use-inspired research and some of the user facilities are available free-of-charge for non-proprietary work if the user intends to publish the research results in the scientific literature."*

[80] https://www.class-central.com/course/france-universite-numerique-comprendre-les-nanosciences-10817
[81] https://www.fun-mooc.fr/courses/course-v1:UPSUD+42003+session02/about
[82] https://actions.maisondelachimie.com/colloque/chimie-nanomateriaux-et-nanotechnologies/

In addition to sources of relevant and accurate information on nanotechnology, there are many poor and inaccurate ones[83] that should be identified and discredited. Probably the best way to do this is to maximise the amount of good information so that the probability of hitting the bad information is reduced.

In communicating nanotechnology, there is also the aspect of perception to be managed. Some see nanotechnology only as high potential while others only see it as high risk. The truth is probably somewhere in the middle as all materials carry some risk and there are many illustrations already of the potential of nanotechnology. In the past it has suffered on occasion from comparisons with GMOs and asbestos, although to date there is little (if any) evidence of any dangers of properly handled nanomaterials. Therefore, in technology transfer of nanotechnology, all stakeholders need to be well-informed (to the level they require) and the mechanisms need to be in place both to manage all aspects of nanotechnology, including its risks and rewards.

Attitudes to nanotechnology generally vary according to the purpose for which it is being applied. For example, in health the public is much more willing to accept nanotechnology (and even for high risk procedures) to achieve benefits that can be life-prolonging or enhance the quality of life. If nanotechnology can reduce the need for unpleasant radiotherapies (or shorten the treatment time), it is very welcome to the patient. In contrast, for nanotechnology in food or cosmetics greater justification may be needed e.g. for nanotechnology in sweets. Attitudes are different again for electronics: critical dimensions in electronic components reach 10nm, 7nm even 5nm but who would reject a computer or a phone that is faster, offers more functions and has less energy consumption? There is 'Nano inside' and it is widely (almost unanimously) accepted. Thus, all 'nano' are not equal – or are not regarded as being equal. Indeed, reducing to the nanoscale may enable a significant reduction in the use of materials or may provide a substitute material to help against the existence of 'conflict minerals' (e.g. tin, tungsten, gold and tantalum) that are mined in conflict zones and can fund the conflict.

Perceptions of nanotechnology can also be helped by better understanding and communication, the first step in that often being achieving a shared language. Engagement of human and social sciences in projects in disruptive technologies can provide a tool for communication of nanotechnology with other disciplines.

[83] For example, an Indian "Nanotech Industry" found on http://apctt.org/nanotech/sites/all/themes/nanotech/pdf/transfer%20of%20nanotechnologies.pdf

3 CONCLUSIONS FOR POLICY

Policies for technology transfer need to be long-term and consistent, particularly for high-tech, high-risk areas with a long time to fruition, such as nanotechnology. It is impossible to have a blanket approach to the development of a "best-practices" menu. Indeed, each innovation eco-system has its own peculiarities, which should be understood and correctly addressed through a customised technology transfer approach.

Policies should include actions for both the short term (for nanotechnology ideas that are close to the market and need a final push) and the long term (for high potential applications that are just appearing on the technology horizon).

The benefits of successful technology transfer are clear – economic and societal – making it a priority for policy-makers in Europe and EU Member States to address gaps, mismatches, barriers and system failures. They should address blockages and support technology transfer on both the supply and the demand side.

Policy should foster knowledge development and transfer, strengthen the links between science and industry and between small and large industries in nanotechnology, and ensure clarity in standards, regulations and guidance for nanotechnology and nanomaterials and their uses.

Policy actions to support nanotechnology transfer have been identified in this context, including:

1. Acting now to achieve a standardised and accepted definition of nanotechnology that can be used throughout the EU (at least) and recognised globally. This is essential for many areas, not least for standards and regulations, for safety at work and for consumers, but also to enable manufacturers to produce and sell nanomaterials and nanotechnology-based products.
2. Using standards to both stimulate the growth of nanotechnology markets and ensure the quality of European products and products fabricated in the EU, thereby also protecting the EU nanotechnology market from sub-standard imports.
3. Providing long-term support for nanotechnology research when applicable (ensuring continuation of research beyond the lifetime of individual projects) both via Horizon 2020 and national/regional funding.
4. Supporting the whole value chain of nanotechnology through public or private funds, identifying the gaps where public funds are needed, and especially financing the most promising and highest potential innovations to enable them to achieve demonstration, pilot production, scale-up and full-scale deployment, surviving the Valley of Death. In conjunction, accepting that return on investment requires patience and long-term investment in nanotechnology, requiring rethinking of established research, investment and business models.
5. Exchanging and fostering good practice in nanotechnology transfer - customising it where necessary - for example, drawing on models of education that foster entrepreneurs; and models of collaboration based on co-creation, with a mixture of technology and industry people working together to bring nanotechnology to market relevance, particularly important given the transversal nature of nanotechnology.
6. Accepting reasonable failure without excessive penalty in all parts of the nanotechnology value chain but especially for nascent business ideas and entrepreneurs, and promoting actions that can support change of mindset.
7. Enabling the movement of academics out to industry (e.g. creating a start-up or being employed in a company) but ensuring that they have a normal route of return, whether that venture into business works out or not. This is very important in areas such as nanotechnology where good ideas currently have a high rate of failure.
8. Supporting (and using as role models for others) hubs for nanotechnology that demonstrate their good understanding of the needs of the community; that provide holistic and

complementary services to drive forward an emerging industry; and that offer a services portfolio that can seamlessly cover the most critical stages of development.

9. Drawing on existing structures and networks (e.g. platforms, pilot lines, test beds) to further support nanotechnology-related entrepreneurship through enhanced measures for networking, mentoring and skills development (technical and non-technical skills).
10. Scanning the horizon for high-potential innovations in nanotechnology, at EU level (e.g. the ICT Innovation Radar), nationally and at research organisations (with research/innovation managers having a good overview of projects so that they can identify those most likely to succeed , for prioritisation of resources and to enable dedicated technology transfer offices to help researchers achieve realistic expectations for their work) and identifying potential entrepreneurs who need support to bring their ideas forward.
11. Broadening the training and education in universities and other academic institutions to include entrepreneurship and innovation management skills while also seeking to attract those with commercial as well as technological expertise into roles as technology transfer managers and patent lawyers, where complementary technology and business skills are needed.
12. Foster the understanding by academic researchers of intellectual property through a short period of training ("nano-IP 101") in patents, copyright, trade secrets and trademarks, licensing and nanotechnology transfer at the start of their research careers.
13. Developing and maintaining infrastructure for nanotechnology that appropriately takes into consideration both technology push and market pull aspects and user needs, the purpose of the infrastructure and user needs. Through collaborative efforts and exchanges at EU level (such as ESFRI), duplication of facilities and effort can best be avoided, and the use of facilities optimised through exchange of best practice. Optimal use of publicly-funded nanotechnology-related infrastructure for public good may require a review of State-aid rules affecting industry use of facilities and consideration of exceptions. Continue and grow the appropriate use of EU-funded facilities for nanotechnology, such as those of the Joint Research Centre.
14. Acknowledging the importance of the role of pilot plants and demonstrators as paths bring research across the Valley of Death towards marketability, particularly in challenging areas such as nanotechnology, to support such facilities and their use, linking such facilities where appropriate and increasing good practice activities in awareness and interactions between stakeholders.
15. Supporting nanosafety and risk research, including encouraging better (interdisciplinary) communication between material science and risk research. This includes defining protocols that are representative of real situations (in vivo or in vitro, with real water as opposed to sterile laboratory water) and protocols of measurements and standards for equipment.
16. Encouraging the translation of nanosafety research into regulatory tools via EU and international cooperation.
17. Thinking "safe by design" whenever appropriate, in preference to a subsequent need for remediation of a problem engendered by new products or new nanotechnologies.
18. Encouraging and enabling partnerships between large companies and SMEs, to strengthen the SME and develop the nanotechnology so it has potential for the large company.
19. Helping nanotechnology start-ups to find customers in order to maintain their presence as an important part of the European ecosystem, e.g. by bringing start-ups to international fairs under a "big company umbrella" and encouraging larger companies to grow their relationship with SMEs in support of a stronger EU nanotechnology transfer environment.
20. Providing balanced and accurate information on nanotechnology for all stakeholders according to their needs, ranging from product data sheets and handling advice for manufacturers to nanotechnology MOOCs.

21. Enhancing communication between nanotechnology stakeholders, increasing awareness and promote links between providers, funders, financiers, users (for a process or product) and consumers of nanotechnology.
22. Becoming better at publicising the strengths of the EU in nanotechnology, as one means of enhancing technology transfer. This would mirror the behaviour of other countries and it would enable the EU to retain a more complete history of nanotechnology advances and actions despite changes in administration, thereby facilitating learning from past nanotechnology policy- and programme-related experiences.

ANNEX 1- AGENDA

Thursday 18 October

WELCOME ADDRESSES
From 9:30 to 09:50
Michele Emiliano, President of Apulia Region
Massimo Inguscio, President of the Italian National Research Council (CNR)
Giancarlo Caratti, Head of Intellectual Property and Technology Transfer Unit, Directorate-General Joint Research Centre, European Commission

SETTING THE SCENE
From 09:50 to 11:00
Giuseppe Gigli, Director of NANOTEC - Institute of Nanotechnology, Italian National Research Council (CNR)
Soren Bowadt, Deputy Head of Unit Advanced Materials and Nanotechnology, Directorate-General for Research and Innovation, European Commission
Arnd Hoeveler, Head of Unit Consumer products Safety, Joint Research Centre, European Commission
Laura Esposito, Policy officer, Research Infrastructures Unit, Directorate-General for Research and Innovation, European Commission
Christian Busch, National Contact Point Nanotechnology for Germany, FET

CHALLENGES AND BEST PRACTICES OF TT IN NANOTECHNOLOGY: THE POINT OF VIEW OF UNIVERSITIES AND RESEARCH CENTERS
From 11:30 to 13:00

Session rapporteur: Francesco Matteucci, *Nanotechnology Living Lab Manager, DHITECH*

Best practices:
Francesco Bonaccorso, *Deputy of Innovation, Graphene Flagship, IIT Graphene Labs & Be Dimensional Srl, Genova*
Simon Baconnier, *Programme Manager on Nanomedicine, CEA-Leti*
Bernard Denis, *Knowledge Transfer senior advisor, CERN*

Round table: Challenges, barriers and opportunities
Matteo Bonfanti, *Technology Transfer Director, the Italian Institute of Technology*
Vincent Jamier, *Group Leader Technology Transfer, LEITAT*
Pascal Colpo, *Team leader, Directorate for Health, Consumer and Reference Materials, Directorate-General Joint Research Centre, European Commission*
Michael Salter, *Technology and Business Development Manager, RISE*
Marco Rossi, *Professor of Experimental Physics of Matter, Sapienza University, Rome*
Corinne Monnier, *Head of "Material Sciences and Engineering" service/Manager, Centre national de la recherche scientifique (CNRS)*

CHALLENGES AND BEST PRACTICES OF TT IN NANOTECHNOLOGY: THE POINT OF VIEW OF SPINOFFS AND STARTUPS
From 14:00 to 15:30

Session rapporteur: Roberto Giannantonio, *Nanotechnology Living Lab Manager, DHITECH*

Best practices
Alessandro Sannino, *Chief Project Scientist, Gelesis*
Andrew Wilkinson, *CEO, Graphene Enabled*
Vivienne Williams, *Chief Executive Officer, Cellix*
Assaf Anderson, *Co-Founder, Materials.Zone*

Round table: Challenges, barriers and opportunities
Alessio Beverina, *Founder and Managing Partner, PANAKÈS*
Heber Verri, *CEO & Cofounder, PhD TT - Technological Transfer Director, Pairstech Capital Management Llp UK*
Jean Charles Guibert, *Senior advisor to the CEO for innovation, CEA*
Matthias Keckl, *Project manager, Fraunhofer Venture Lab*
Katrien Meuwis, *Senior Manager IP Business & Intelligence, IMEC*

Friday 19 October

KEYNOTE SPEECH
From 09:00 to 09:10

Standardization activities supporting safe and sustainable development of innovative nanotechnology
Emeric Frejafon, Chairman, European Committee for Standardization/CEN TC352

PUBLIC AND PRIVATE INITIATIVES FOSTERING TECHNOLOGY TRANSFER IN NANOTECHNOLOGY
From 09:10 to 10:00

Fabio Taucer, Policy Officer, Directorate-General Joint Research Centre, European Commission
Bernd Reichert, Head of Unit, SMEs in Horizon 2020, European Agency for Small and Medium Enterprises
Alessandro Apa, Senior Fund and Structuring Officer, European Investment Bank
Roberto Volpe, Junior Adviser, Italian Ministry of Economic Development, DG for Industrial Policy, Competitiveness and SMEs
Steven Tan, Director, Nascent Ventures

CHALLENGES AND BEST PRACTICES OF TT IN NANOTECHNOLOGY: THE POINT OF VIEW OF THE INDUSTRY AND SMES
From 10:30 to 12:00

Session rapporteur: Mattias Dinnetz, *Innovation and Technology Transfer Officer, Directorate-General Joint Research Centre, European Commission*

Best practices
Daniela Sottocornola, *CEO, BIOTEC*
Anurag Bansal, *Global Business Development Manager, Acciona R&D*
Jukka Nieminen, *President, Beneq Oy*
Round table: Challenges, barriers and opportunities
Luciano Socci, *Patents & Know how manager, Pirelli Tyre S.p.A.*
Claire Skentelbery, *Director General, Nanotechnologies Industries association*
Sergio Galbiati, *Vice Chairman, LFoundry*

Giovanni Baldi, *Director, Centro Ricerche Colorobbia Consulting*

WRAP-UP AND POLICY RECOMMENDATIONS
From 12:00 to 13:00

Speakers:
Francesco Matteucci, *Nanotechnology Living Lab Manager, DHITECH*
Roberto Giannantonio, *Nanotechnology Living Lab Manager, DHITECH*
Mattias Dinnetz, *Innovation and Technology Transfer Officer, Directorate-General Joint Research Centre, European Commission*
Round table: Wrap-up and policy recommendations
Jean Charles Guibert, *Senior advisor to the CEO for innovation, CEA*
Vivienne Williams, *Chief Executive Officer, Cellix*
Claire Skentelbery, *Director General, Nanotechnologies Industries Association*
Steven Tan, *Director, Nascent Ventures*
Anurag Bansal, *Global Business Development Manager, Acciona R&D*
Soren Bowadt, *Deputy Head of Unit Advanced Materials and Nanotechnology, Directorate-General for Research and Innovation, European Commission*

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