NMP Expert Advisory Group Orientation Papers on Industrial Innovation

RESEARCH AND INNOVATION POLICY

EUR 25393 EN

EUROPEAN COMMISSION

Directorate-General for Research and Innovation
Directorate G — Industrial Technologies
Unit G.1 — Horizontal aspects

Contact: Nicholas Deliyanakis

European Commission
Office CDMA 6/158
B-1049 Brussels

Tel. (32-2) 29-95526
Fax (32-2) 29-91848
E-mail: Nicholas.deliyanakis@ec.europa.eu

EUROPEAN COMMISSION

NMP Expert Advisory Group Orientation Papers on Industrial Innovation

Directorate-General for Research and Innovation
Industrial technologies / NMP

2012

EUR 25393 EN

EUROPE DIRECT is a service to help you find answers to your questions about the European Union

Freephone number (*):

00 800 6 7 8 9 10 11

(*) Certain mobile telephone operators do not allow access to 00 800 numbers or these calls may be billed

LEGAL NOTICE

Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use which might be made of the following information.

The views expressed in this publication are the sole responsibility of the author and do not necessarily reflect the views of the European Commission.

More information on the European Union is available on the Internet (http://europa.eu).

Cataloguing data can be found at the end of this publication.

Luxembourg: Publications Office of the European Union, 2011

ISBN 978-92-79-25543-4
doi 10.2777/7187

Printed in Belgium

)

European Commission

EUR 25393 — NMP Expert Advisory Group Orientation Papers on Industrial Innovation

ISBN 978-92-79-25543-4
doi 10.2777/7187

]

NMP Expert Advisory Group

Orientation Papers on Industrial Innovation

Executive Summary

The central role of innovation in the creation of jobs and wealth is stressed in the Europe 2020 strategy and the Innovation Union flagship initiative. In this context, the NMP Theme[1], with its focus on smart and sustainable growth, and its successor activities under Horizon 2020 have a primary role to play.

With this in mind, the NMP Expert Advisory Group (EAG) held a two-day workshop on 4-5 November 2010 to identify practical steps for improving the economic and social impact of R&D in the NMP areas, nanotechnology, materials and production technologies. It was also recognised that more fundamental research also plays an important role and should be better linked to the more applied research and innovation. To support future strategy, EAG members completed five orientation papers to help the Commission assess experience from the NMP fields with a view to the future, with some recommendations on how innovation could be better supported. The five orientation papers outlined here are:

– Interactions between academia and industry

– Best practice in innovation

– Simplification and SME involvement

– Metrology and Standards in Innovation

– Key Enabling Technologies of interest to the NMP Theme

Each paper offers novel insight and practical recommendations built on the expertise of leading practitioners in its respective field and stands as an important contribution in its own right. However, all five papers are mutually synergistic and collectively address and enhance the opportunities offered for accelerating innovation in Europe's industrial technology sectors, within the Competitive Industries pillar in Horizon 2020.

In the remainder of its term, the NMP EAG intends to continue work on key enabling technologies; clusters of projects and dissemination of results; role of the European Institute of technology in smart regional innovation and international cooperation.

Interactions between Academia and Industry

The need for a more efficient knowledge transfer between university and industry is led by common interests and mutual benefits. For industry, this interaction facilitates access to state-of-the-art research, while academic partners benefit from the opportunity of applying research results, from access to facilities and from a private source of funding. Commercialisation, mutual learning, access to funding and access to in-kind resources are some of the main motivations for academia-industry collaboration, which can follow a partnership model (e.g. collaborative research) or a service one (i.e. academic researchers work under the direction of industrial clients).

A typical difficulty in these interactions is the mismatch between the objectives of academic and industrial partners, which is linked with their different cultures (e.g. curiosity versus goal-

[1] Nanosciences, Nanotechnologies, Materials and New Productions Technologies

driven research, publishing versus exploitation of results, desire to be at the "cutting edge" of research versus development of previous research).

The following approaches can help strengthen the links and lead to more effective innovation from research results:

– Research-based model: focusing on longer-term industrial issues with wide dissemination

– Student-based model: focusing on mobility of researchers between academia and industry

– Simplification and SME involvement

- Long-term, close collaborations, in jointly determined areas (such collaborations can both preserve academic freedom and lead to effective innovation).

- Top-up or two-stage funding for projects with innovation potential.

- Good project management and follow-up are essential: this includes commitment, continuity and communication.

The European Union has developed several structures to create the appropriate condition for a dialogue between academia and industry: European Technology Platforms (ETPs), Joint Technology Initiatives (JTIs), the European Institute of Technology (EIT), brokerage events, workshops, etc. Similar initiatives exist in Member States.

Best practice in innovation

Linked with university-industry collaboration, there is a growing recognition of open innovation models, developed in many leading companies. Open innovation may be described as a funnel of ideas towards development and commercialisation, in which several actors interact: end-users, research centres, academia, different industries from different disciplines, regulators, tax-payers, etc. Open innovation means "co-creation": joint research, joint development, joint evaluation, joint validation of novel products and solutions.

Three models can be described: (i) *Large industry model*, implemented in multinationals like Intel, Bayer, BASF, Philips, etc. (ii) *Regional industry-led "Open Innovation" Centre Model*, typically based near a major industrial company and supported by public development funds and creates support for SMEs. (iii) *Regional University-Industry "Open Innovation" Centre Model*, centres of industrial collaboration based on the campuses of academic centres of excellence, which serve large companies and SMEs on a fee for access basis. They are very useful for SMEs to facilitate access to technology and networking.

Funding remains problematic in Europe for the later stages (since prototype demo to technically qualified final product) of the research and innovation continuum. Instruments have nevertheless been developed at EU level, such as public-private partnerships (PPPs), Innovation Partnerships or the Competitiveness and Innovation Programme (CIP). Other actions still need to be improved for innovation, as public procurement or simpler, faster and cheaper Intellectual Property (IP) regulations.

A *total system approach* for innovation is needed. This should include, amongst others:

- Stimulation and creation of open innovation actions, according to the three models.

- Creation of a European Innovation Council, similar to the ERC, to finance *innovator-driven* projects.

- Creation of a European Regional Innovation Fund.

- Higher engagement with Venture Capital Funds.

- Undertake foresight studies on future "hot areas" of technology development.

The three models described point towards the importance of “smart regional specialisation” for realisation of best practice in innovation. The recommendations address practice, capacity building and funding instruments.

Simplification and SME involvement

SMEs (i.e. companies employing less than 250 people, and with an annual turnover below 50 Mio € or a balance sheet not exceeding 43 Mio €) represent 99% of all companies in Europe and employ 65 million people. In spite of these impressive figures, their participation and success rate in the Framework Programmes remains low. To boost SMEs innovation, the European Commission should create a flexible, lightweight and well-defined form of partnership for them. This would imply a shift towards a trust-based and risk-tolerant approach from the EU. More concretely, it would be necessary to develop, amongst others:

- A smaller variety of financial rules: no ex-ante financial capacity checks, exemption of certificates on financial statements, maintenance of a single entry registration capacity and eFP to be intensified.

- Time to grant should follow the same model than the ERC (less than 20 days).

- Use a two-step proposal submission, with pre-proposals to be developed if successful

- Move from a cost-based funding to a results-based and IPR approach.

- Complement grants with loans.

- Reduce reporting obligations.

- Integrate the possibility of allowing SMEs of entering a project in its latest stage or as sub-contractor.

- Reduce the size of consortia, to avoid SMEs isolation and minor role.

For enhancing innovation, the FP should be more industry oriented and driven as it is today, moving from an evaluation impact criterion of "pure excellence" towards an "excellence and exploitability of results and interest for the community".

Metrology and standards

It is widely acknowledged that metrology and standardisation provide vital support to R&D and to the development of innovative products and processes, through improved industrial efficiency and reduction of risks and transaction costs in the market. The European Union acknowledges the relevance and importance of standardisation to innovation in several official documents and, indeed, has launched a major programme on measurement (400 million € in FP7), involving National Metrology Institutes and other research organisations. Last but not least, the European Commission uses mandates to the European standardisation organisations, like CEN, CENELEC and ETSI for developing standards which are important for meeting EU policy objectives.

There are nevertheless several barriers for an effective transfer of research outputs into standards. For instance, timeframes are rarely aligned between research and standardisation, and there is often a lack of interest from researchers, who move in different circles. EU actions towards standardisation are often fragmented and it is difficult to find funding for pre- and co-normative research. Support is often needed on a relatively smaller scale and does not fit easily with large scale projects in the current framework of calls. A new approach is needed and could be developed in liaison with A185 initiative on European Metrology Research Programme.

An interesting case study that demonstrates the links between innovation and standardisation and metrology is provided by the position of Environment, Health and Safety (EHS) research for nanotechnologies. Uncertainty related to EHS impact of nanotechnologies is recognised as a key potential barrier to innovation in this area. In recent years, the NMP programme has invested heavily on EHS issues. Activities have included reviews, assessment of existing methods and research to fill knowledge gaps.

However, the work is somewhat fragmented and the EHS programme under the NMP theme is not fully integrated in the innovation-led FP7 work. It would be necessary for the innovation process to move forward with confidence that the EHS and societal issues are being addressed, which requires further links between EHS and the innovation chain, as the NanoSafety cluster is now trying to do.

Some concrete recommendations are:

- Identifying and prioritising standards needs to support European innovation;
- Using metrology and standards recommendations in EU foresight projects for future calls;
- Using standards impact as a performance indicator for projects;
- Creating a single focus within DG Research for metrology and standards;
- Facilitating access to SMEs to measurement and characterisation expertise and tools;

For Nano-EHS:

- Developing common databases for information sharing and funding transnational work; and
- Creating a single European centre, probably from a small number of institutions, for primary repository of information concerning potential risks of nanomaterials.

Key Enabling Technologies

Key Enabling Technologies (KETs) are knowledge and capital intensive technologies with high R&D intensity, rapid and integrated innovation cycles and highly skilled employment. Their influence is pervasive, enabling process, services and product innovation throughout the economy. They are multidisciplinary and trans-sectoral and led to convergence, technology integration, having the potential to induce structural changes.

Conscious of their relevance, the EU launched in 2010 a High Level Group that identified six areas: photonics, manufacturing, nanotechnologies, biotechnology, advanced materials and micro/nanoelectronics. Seven working groups were then established, to analyse topics like inter-disciplinarity, value chain and vertical integration, research enhancement, product development launch, policy benchmarks and options or financial instruments.

The "valley of death" concept was analysed in the mid-term report, with case studies (e.g. solid state lighting, nanoelectronics, photovoltaics). A SWOT and a value chain analysis identified a double condition for sustainability: technology capability and manufacturing capacity. This leads to two general recommendations:

- Increasing support to pilot and demonstration activities. To obtain enough impact, large-scale integrating projects should be considered.

- Giving more emphasis to the integration part of the NMP programme, not only in terms of budget share but also as a strategic activity line.

More specific recommendations are provided for each of the six KET areas. The work on recommendations in the field of Key Enabling Technologies will be continued.

I. Interactions Between Academia and Industry

Costas Kiparissides (Rapporteur)

Rob Aitken, Livio Baldi, Marie-Isabelle Baraton, Leah Boehm, Eduard Hulicius, Jennifer Melia, Helena Van Swygenhoven and Terry Wilkins

Supported by Nicholas Deliyanakis, Anne Mallaband and Nathalie van Neck (European Commission)

1. Introduction

The concept of university and industry (UI) research collaboration is not an invention of the 21st century, but has existed since the 1800s in Europe and since the industrial revolution in the United States. The period 1980-2000 was characterized by a marked transformation in the mode of governance of university-industry interactions. The traditional models were personal contracts between academic scientists and company researchers, and intermediation through dedicated public research centres. However, new methods have been developed to achieve prompt transfer and exchange of knowledge, which is crucial for firms facing continuously increasing competition from low cost producers, and rapid obsolescence of products. Many attempts (in different countries) have been made to develop a new institutional infrastructure able to support knowledge diffusion between universities and firms. A central tenet of these new systems is that the university must take an active part in the governance of knowledge transfer. Knowledge transfer is becoming institutionalized, and seen as a new role conferred on the university, rather than on individual university researchers or public research organizations. This qualitative change in the nature of the relationships between industry and academia has been accompanied by the emergence of visible new organizational forms such as university-industry liaison offices, technology licensing offices, technology transfer offices, industry-university research centres, research joint ventures, university spin-offs and technology consultancies. It has also entailed the development of a new set of ‘rules of engagement’ to coordinate the interactions between academic and company scientists. These partnerships have, however, increased and intensified over the past decade and have received much public and institutional attention. The growth of UI research collaboration is due to various factors. More effective and efficient knowledge transfer for the benefits of the industry and more funding opportunities for the benefits of academic researchers are two key factors. Furthermore, the industrial partner benefits from direct access to state-of-the-art research, can potentially influence the research agenda, and can experience a positive effect on the overall corporate culture as a result of the collaboration. At the same time, the academic partner benefits from the opportunity to apply research results to market products, from access to good facilities, and from gathering first-hand information about the state of the market. It stands to reason, therefore, that UI research collaborations will continue to grow in number, making it relatively safe to say that it is a very promising model for innovation.

It is largely documented that public science has a positive impact on industrial innovation. Previous studies, for instance, provide evidence for enhanced corporate patenting and improved new product and process development in the corporate sector through scientific research results. However, most of these empirical studies focus on the U.S.

For the European Economic Area, scholars and policy makers are rather sceptical with respect to emphasizing a large impact of science on corporate innovation: it has been claimed for about a decade that a so-called “European Paradox” exists. It describes the phenomenon that EU countries play a leading global role in terms of top-level scientific output, but lag behind in the ability of converting this strength into wealth generating innovations in the business sector.

An empirical analysis of 4,000 German academic patents revealed that corporations favour collaborative agreements with academia that enable them to reap short term rather than, possibly more uncertain, long term returns. It was shown that, in the European context, firms strive for academic inventions with a high blocking potential in technology markets. Academic patents issued to corporations appear to reflect less complex and fundamental inventions as compared to inventions that are patented by the science sector as is reflected by their forward citation pattern. The results support the argument that a weak corporate sector explains part of the European paradox. Firms seem to lack the necessary absorptive capacity that would enable them to identify and acquire the most promising scientific inventions possibly enhancing long term growth and competitiveness. As this is a necessary first step before commercialization can take place, firms and policy makers should pay attention to strengthening this stage of science-industry knowledge transfer. It is questionable whether it is a successful long-term strategy to focus on rather short-term benefits from science than aiming for the adoption of more complex and more basic university technologies.

This report presents the different modes of academia-industry interactions, the motivations and benefits for university-industry engagement, the typical obstacles, the industry-academia partnership models and the opportunities & risks. In addition, it refers to ways of bringing the right academics in contact with the right industry and ways of fostering academic freedom while ensuring knowledge transfer. Finally, some ways to improve collaboration and build bridges between academia and industry are suggested.

2. Modes of Academia - Industry Interactions

Table 1 presents the multifaceted nature of university-industry interactions.

Table 1. University-industry interactions.

• Research partnerships	• Inter-organizational arrangements for pursuing collaborative R&D
• Research services	• Activities commissioned by industrial clients including contract research and consulting
• Academic entrepreneurship	• Development and commercial exploitation of technologies pursued by academic inventors through a company they (partly) own
• Human resource transfer	• Multi-context learning mechanisms such as training of industry employees, postgraduate training in industry, graduate trainees and secondments to industry, adjunct faculty

•	Informal interaction	•	Formation of social relationships and networks at conferences, etc.
•	Commercialization of property rights	•	Transfer of university-generated IP (such as patents) to firms, e.g., via licensing
•	Scientific publications	•	Use of codified scientific knowledge within industry

Regarding to relationship-based forms of university-industry links, we distinguish between two main types, depending on the degree of finalization of the research undertaken: 'research partnerships' and 'research services'. In light of these considerations, research partnerships are designed to generate outputs that are of high academic relevance and can therefore be used and adapted for academic publications by the researchers involved. Research partnerships include collaborative research activities, also known as sponsored research, and university–industry research centres. Research services, by contrast, are provided by academic researchers under the direction of industrial clients and tend to be less exploitable for academic publications. Contract research and some academic consulting fall under this category.

The term 'university-industry knowledge transfer' is used to indicate a wide range of interactions at different levels, involving various activities aimed mostly at the exchange of knowledge and technology between universities and firms. These interactions on the side of universities are often described as 'third stream' or 'third mission' activities. They include, for example, collaborative research with firms, contract research and academic consulting commissioned by industry, the development and commercialization of intellectual property rights (IPRs), the creation of start-up firms to exploit university inventions, co-operation with firms on graduate training, and training and exchanges with industry researchers.

Figure 1 illustrates the various factors that influence the 'structure' of collaboration.

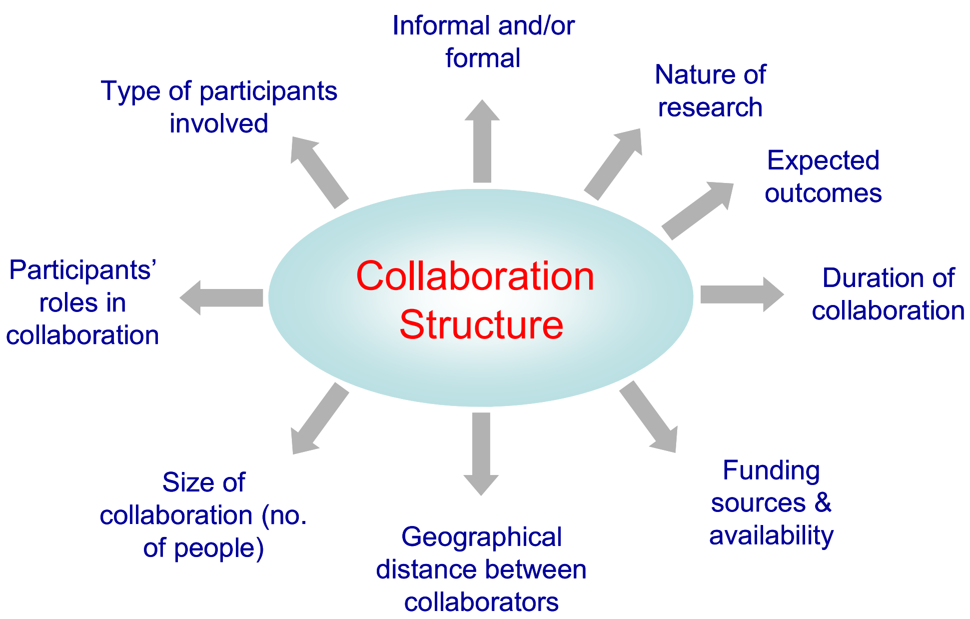


Figure 1: Elements of collaboration structure.

3. Motivation

Regarding what motivates academics to engage with industry, using both informal collaboration and formal models of interaction, four main motivations have been identified: i) commercialization (i.e., commercial exploitation of technology or knowledge), ii) learning (i.e., informing academic research through engagement with industry), iii) access to funding (i.e., complementing public research monies with funding from industry) and iv) access to in-kind resources (i.e., use of industry-provided equipment, materials and data for research). Three of these factors are research-related and only one is related to an intention to be entrepreneurial. In fact, our results suggest that most academics engage with industry in order to further their own research, either through learning or through access to funds and other resources. In addition, commercialization on average was ranked lowest by our survey respondents. Table 2 shows examples of motivations for the engagement of universities with industries.

Table 2. Examples of motivations for university-industry engagement.

University	Industry
• Enhancement of teaching	• Sourcing latest technological advances (obtain a window on science and technology, including access to knowledge, artefacts and technical information)
• Funding / financial resources (industry provides a new source of money. This helps diversify the university's funding base and provides opportunities for obtaining state-of-the-art equipment and facilities)	• Laboratory usage (gain access to university facilities)
• Industrial money involves less red tape than government money	• Personnel resources /cost savings
• Source of knowledge and empirical data (industrially sponsored research provides students exposure to real world research problems)	• Risk sharing for basic research
• Work on an intellectually challenging research programme which may be of immediate importance to society	• Stabilising long term research projects
• Enhancement of reputation	• Recruiting channel (obtain access to manpower)
• Job offers for graduates (provide better training for the increasing number of graduates going to	• Obtain prestige or enhance the company's image

industry)	
• Some government funds are available for applied research, based upon a joint effort between university and industry	• Provide general support or technical excellence
• Political pressure	• Foster good community relations

4. Benefits

Table 3. Advantages of academia-industry research partnerships.

Advantages for Industry	Advantages for Universities
• Outsourcing: getting research done by university researchers when the company is unwilling or unable to do it in-house; low cost collaboration – value for money.	• Market awareness: gaining insights into the research problems preoccupying particular companies or industrial sectors; developing new lines of (industrially relevant) research.
• Complementing the company's skills base: accessing skills and expertise within universities which company staff lack.	• Maintaining momentum: increasing the chance of sustaining existing research programmes and initiating new programmes by widening the customer base.
• Pursuing a multidisciplinary approach: deploying the multi-disciplinary teams which universities can more readily assemble.	• Harnessing private and public funding: bringing private (as well as public) funding to bear upon research programmes by developing proposals in partnership with one or more companies.
• Harnessing public funding: bringing public (as well as private) funding to bear upon company research problems by developing proposals in partnership with a university.	• Complementing the university's skills base: learning new techniques and skills, developed within companies.
• Complementing the company's physical resource base: accessing unique or specialist university-based equipment, facilites (and services) which the company lacks.	• Complementing the university's physical resource base: accessing state of the art or specialist company-based facilities or services which the university lacks.
• Recruitment made easy: finding the right staff for the job as a result of getting to know students, post-doctoral researchers and academic supervisors.	• Enriching teaching programmes: obtaining the employer's perspective on the direction and content of teaching programmes; sourcing ideas for student projects and locating placement opportunities.
• Benefiting from new ideas: getting the inside track on emerging fields, enabling technologies and new ideas, generated within universities, which could benefit the company; maximizing the potential for innovation.	• Sourcing job opportunities: getting the inside track on possible job opportunities for graduates, post-graduates, post-doctoral researchers and academics.

- Opening up a window into the world: keeping tabs on relevant developments elsewhere in the world via academics' extensive international networks.

5. Typical Obstacles

One of the typical major obstacles to a university-industry collaboration is the lack of adequacy between the objectives of the two partners. While some in industry are looking for tangible results, performance and marketable products on a short time scale, the others in academia are looking for fundamental understanding of phenomena without time constraint and without any barrier to imagination and creativity. A successful and sustainable collaboration is possible only if both parties can achieve their objectives with benefits for both. Developing a "win-win" strategy is the key for success. The adequacy of the objectives is therefore critical for a fruitful collaboration because creative and high-quality research (with articles published in high-ranked journals) may be useless for industry, at least on the short or medium term. Unless objectives and methods of a research project are aligned with the strategy and needs of a company, the collaboration may not be worth the investment. Such alignment will also ensure that results of the research are directly taken up by industry on a very short time scale. In what follows, the typical obstacles are presented in detail.

5.1 The Two Cultures

Many of the obstacles to successful collaboration and communication are based on deep cultural differences between industry and academia. These differences are desirable and necessary for the effective functioning of each culture. Both cultures have changed significantly in the past decade, but these changes have not necessarily made the two cultures more similar. Attempts to significantly change either culture to make them more similar will undoubtedly meet with little success. Even if it were possible to change the cultures to make them more similar, we would then lose many of the most important strengths of each culture, resulting in a net loss to the common good. It makes more sense to learn about and respect each other's culture, and look for ways to work together effectively. We will review the major cultural differences and discuss some possibilities for finding mutually acceptable middle ground.

5.2 Curiosity vs Goal-driven Research

Academic research tends to be curiosity-driven. Academic scientists often have the luxury to pursue new knowledge for the knowledge's sake. Industrial research tends to be more goal-driven. There is usually a need to learn some particular piece of knowledge by a deadline to achieve a competitive advantage in the marketplace. Longer-term research generally does not fare well in an environment strongly focused on product development and quarterly profits. This creates a situation where incremental improvements become the only viable mode for progress. This approach is clearly very profitable in the short term. However, history has repeatedly shown the unpleasant results of this approach in the long term.

Industry has often collaborated with academic scientists with the goal of developing new products. However, the research universities have no natural advantage in product development. Industry tends to define projects quite narrowly. This actually deprives industry of some of the major strengths of academia: creativity, originality, and intellectual power.

One way" to bridge this cultural difference is to analyze the longer-term technical goals of the industry, and then define a general research area for academic scientists. Jointly determining areas where the academic scientist can conduct interesting, publishable research, that also furthers the longer-term interests of the industry, can be mutually satisfying and beneficial.

In this paradigm, industry specifies the areas of scientific research where progress would be of practical value, and academia considers how longer-term scientific progress in these areas might best be achieved. Together they decompose the complex technical problems facing industry into the underlying basic scientific issues.

5.3 Proprietary Issues

Academic scientists must present their work at conferences and publish papers in prestigious journals to survive and prosper. Achieving tenure and winning grants depend largely on published evidence of productivity and the establishment of a good reputation in the scientific community. This necessitates open discussion of scientific work with other scientists. In sharp contrast, industry tends to keep scientific work proprietary. This is seen as a way to protect the company's investments in newly acquired knowledge or data. We don't want our competitors to know what we are doing, or give them any technical knowledge that could possibly allow them to improve their products and processes.

One possible way to bridge this cultural gap in interactions between industry and academia is to establish prior agreements on proprietary issues. These agreements would set rules for the sharing of intellectual property, and set a finite time (perhaps six months) for collaborative work to remain proprietary. This gives industry time to file patents, and allows academia to present and publish the scientific aspects of the collaborative work in a timely manner. This also ensures the scientific work is adequately documented and scrutinized by the scientific community.

5.4 Money

In crude terms, research universities convert money into trained scientists and new knowledge, while industries convert trained scientists and new knowledge into money. Ideally, the result is a positive gain in the welfare of the trained scientists, the knowledge developed, and the money made. What can be done to improve the efficiency of this process?

The funding situations in academia and industry are quite different. Academic scientists rely largely on government and foundation grants. Funding for academic research has been declining.

Industrial scientists rely largely on internal funding from the company, which ultimately comes out of the company's profits. The funding is usually for specific product-development projects. Most companies require approval from high-level management to fund a university project for longer than one fiscal year.

Industrial funding of academic research on a year-by-year basis is usually a problem for academic faculties. One possible solution is to pair a working-level industrial scientist with an upper-level industrial manager. The industrial scientist can then interface with an academic scientist, providing meaningful technical input and evaluation, while the upper-level manager can 'bank roll' and provide internal support for the joint project.

5.5 FAD Science

There is a cultural tendency in academia to do research on the latest 'hot' topic. This is reasonable: when a breakthrough like high-temperature superconductivity happens, new scientific territory is opened up for exploration. The perhaps once-in-a-lifetime chance to explore completely new territory and perhaps discover significant new pieces of science is irresistible. Minor fads in scientific disciplines are continuous. The desire to stay at the 'cutting edge' is one motivating force.

Basic industry develops some key technologies and then continues to make profits for many years, well after the technology becomes pass6 in academia. This can lead to a 'disconnection' between academic scientists and industries. The basic industries (metals, chemicals, plastics, autos, and other manufacturing industries) have in many cases eliminated or drastically reduced their internal R&D efforts, in response to short-term economic pressures. This makes the basic industries even more in need of technological help from outside sources. It is easy to lose sight of the many benefits obtainable by injecting new technology into basic industry. The emphasis on job creation may miss the need for job conservation in existing basic industries. Basic industries contribute significantly to the number of jobs available, and it would be detrimental to the nation's needs to focus only on new job creation in high-technology industries. Bridging this gap may require third-party intervention, in the form of government programs.

5.6 The Role of Industrial R&D Laboratories

Some outstanding industrial R&D labs have experienced drastic cuts and changes in mission in recent years. The question has been raised: have these labs completed their function? Do we have all the basic science we need for the foreseeable future, and all we need do is apply that science to product development?

Universities have traditionally trained many scientists who enter the industrial sector and act as a source of new knowledge, concepts, and ideas from basic research. Universities do not usually act as direct sources of new products and new technology that have an impact on industry.

Transforming the knowledge generated at universities into new industrial products or processes has traditionally been done by industrial scientists in an industrial R&D lab. Some functions of industrial R&D labs are to maintain active relationships with academia, provide entry-level jobs to freshly minted Ph.D.'s (smoothing the transition from academia to industry), stay in touch with the latest academic advances in fields of relevance to their industry, and apply the results of basic work done in universities to particular industrial concerns. The industrial R&D labs act as a conduit and intermediary between industry and academia.

Industry needs to encourage its scientists to communicate and collaborate with academic scientists. It is easy for industry to lose sight of the importance of this, since the results are not easily quantifiable and don't show up directly on the quarterly profits. It is necessary to have a place removed from the pressure of quarterly profits to develop scientific advances needed for future products and processes. Academia serves this role very well. Industry should not hold academia responsible for a business model of short-term profits.

5.7 Dealing with Bureaucracy

Overvaluing potential intellectual property can slow down negotiations. What are the key issues to be considered and what are peripheral?

5.8 Different Expectations

Industry

- Information on innovative developments including disruptive technologies
- Technology transfer. Developments to be implemented in industry
- Assistance in solving technical difficulties
- Training of people: engineers, scientists, economists
- Products, sales, market share, profit

Academia

- Freedom of research and activities
- Funding of research
- Funding of students
- Requirements from industry, industrial trends
- People from industry teaching at academic institutes
- Reward (compensation) for working with industry
- IP issues: ownership, patents, publication rules

A summary of the obstacles (barriers), categorized as cultural, institutional and organizational, is given in Table 4.

Table 4. Categories of UIC barriers.

Cultural Barriers
• Divergent missions and goals • Conflicting interests concerning secrecy and IPR • Different languages and assumptions
Institutional Barriers
• Different nature of work • Divergent perception of what the “product” of R&D is

• Structure change and change of responsibilties on the company’s side
Operational Barriers
• Lack of knowledge about the partner and his processes • Insufficient coordination and project management • Lack of acceptance for results generated by the partner

The question is how the different incentive structures for academic researchers and industry staff can be aligned to produce mutually beneficial results. Generally, scientists are oriented towards the reputation-based reward system of open science, while industry scientists face the commercial imperative to produce exploitable results.

Some suggestions are given below:

- Both parties need to be more realistic regarding outputs and timing.
- Academics must understand that an idea or an invention on its own is not a solution.
- Companies must understand that they will not get a product that is ready for market.
- There is a need to build a commercial and marketing awareness in to the planning process at an early stage.
- Building trust and a strong relationship between the partners is crucial.
- Time to contract needs to be optimized.

6. Industry – Academia Partnership Models

Four primary academic-driven partnership models can be identified (Figure 2).

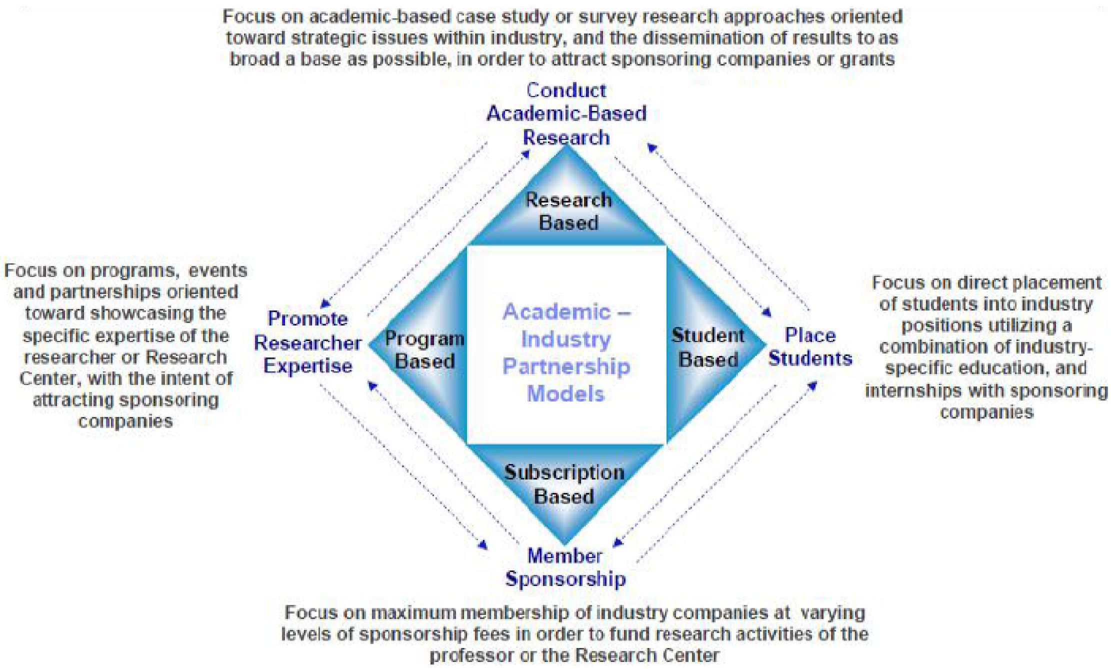


Figure 2: Primary academic-driven partnership models.

Regarding large industries that can afford longer term programs, cooperation with universities/PRO could take place at two levels:

Technology exploration programs on topics that are not at the moment in the core competence of the company but could become important 5-10 years in the future. It is a field for Open Innovation, and critical mass on the side of the research organization (especially if coupled to the availability of some critical facility) is a big facilitator. A good example is IMEC, probably the overall best research centre in Microelectronics that has been able to attract research funding and researchers from outside Europe (Intel, Micron, TI, Toshiba, Hynix, Samsung), in spite of not having any large European industry close by. Public funding here is welcome.

Dedicated cooperation links, normally long term and based on common interest with specific professors and universities on themes which are close to core competence. It is not in general Open Innovation, in the sense that other companies are not admitted to participate. Confidentiality and IP ownership are issues, and funding is mostly private. These relationships in general are used to provide companies with a source of talented young people. Research is a good tool for training them, even if it is not in the field of direct interest to industry.

For the large majority of SMEs, especially the ones below 50-100 people, the time frame is shorter and rather than research (with a longer time frame and unpredictable results) they are interested in having access to specific competence and problem solving services. Normally, it is not very motivating for researchers, and money is the best incentive. The Politechnico di Milano set up a dedicated engineering society to serve this need. In some regions in Italy is is supported by “research vouchers” that SMEs can get with minimal bureaucracy and have to spend in one University. It can be effective for a first access and starting cooperation, but it is mostly on the local level.

7. Opportunities & Risks

7.1. A One Dimensional Definition of Collaboration Effectiveness is Unrealistic

There is no universal definition of success or effectiveness in collaboration because:

- Different participants involved in collaboration (industrialists, academics, government, etc.) have different perceptions or definitions of collaboration success (which can be subjective or objective, or both).
- The definitions of success vary by type of collaborative relationship, each of which has different objectives, procedures and outcomes.
- The definitions of success also depend on the stage of the collaborative process being observed.

7.2 Reasons why Partnerships Work

- Ensuring there is a clear understanding as to the issue to be addressed, how it will be addressed, within what timeframe, and at what cost.

- Establishing and maintaining a clear communication vehicle (status calls / monthly meetings, etc.).
- Driving the activity to completion (vs. letting the activity lag due to lack of focus).
- Bringing in other disciplines / institutions to address the issue.
- Offering to help disseminate results upward / downward within the organization.
- Delivering results in a format compatible with the organization
- Giving organizational-specific examples of how the results impact the organization.
- Over-delivering by answering an extension to the original question.

7.3 Reasons why Partnerships do not Work

- Taking the money and running
- Sharing results with the payer's competitors
- Hiding from your contact when problems occur
- Being too general, or stating the obvious in the results
- Underestimating the experience and knowledge of your contact
- Having all the answers
- Not knowing how the results are to be used…and with whom
- Delivering results: -without offering to formally present and discuss, - without opportunity for questioning, - without an offer for follow-on involvement

7.4 Indicators of Success

A workshop on industry-academia research collaborations run by the National Academy of Science (US) provided several indicators of success that are viewed as common by all participants involved in collaborative research (NAS, 1997, p.13):

- Project milestones are achieved.
- Frequent communication between partners occurs.
- The number of quality publications and student theses resulting from collaborative research is comparable to other productive research areas.
- The number and quality of ideas resulting in follow-up activity shows a mutually stimulating influence among the partners.
- Intellectual property (e.g. no. of patents/copyrights applied for or granted) is generated.

- The number and quality of graduate students or post-doctoral fellows hired by industrial partners are increased.

- Continuity of the relationship extends beyond the initial projects.

- The fiscal status of the partnering company improves.

7.5 How Universities' Research Quality Shapes their Engagement with Industry?

Using a dataset covering all UK universities regarding their collaboration with industry (i.e. collaborative research, contract research and consulting), it was found that in technology-oriented disciplines, departmental faculty quality is positively related to industry involvement. In the medical and biological sciences, a positive effect of departmental faculty quality was found which however does not apply to star scientists. In the social sciences, a slightly negative relationship was observed between faculty quality and particularly the more applied forms of industry involvement. The implication for science policy makers and university managers is that differential approaches to promoting university-industry relationships are required.

The research aimed to examine whether the universities with the most successful researchers are also the ones who work most with industry or whether more 'applied' universities are more successful at establishing relationships with industry despite lower academic standing. This question is highly relevant for policy making that attempts to balance the quality of scientific production with the diffusion of university-generated technologies within the wider economy. The analysis of UK universities revealed that there is no uniform relationship between industry involvement and faculty quality across disciplines. For the technology-oriented disciplines, the researchers in the best departments are also those with high industry involvement. This alignment is due to the high levels of complementarity between academic research and technology development. For disciplines such as the medical and biological sciences it was found that research quality is also positively related to industry engagement but interestingly this relationship reverses for the very best departments. This effect can be attributed to the fact that in these disciplines the complementarities between academic research and industrial requirements are lower and therefore those researchers with the best access to public grants, (i.e. the star scientists), may have to resort to industry funds to a lower degree. For the social sciences, which are less resource-intensive, a mostly negative relationship was found between faculty quality and particularly the more applied forms of industry involvement.

These findings have implications for universities and policy makers keen to promote university engagement with industry and are rather important because, in terms of overall economic impact, the types of industry engagement analysed in this research are more pervasive than IP transfer and academic entrepreneurship. In the technology-oriented disciplines, industry involvement is strongly complementary with top-level scientific research. This means the diffusion of university-generated technologies into the economy is progressed through high quality scientific production and commercialization in these disciplines, and for that reason it may be easier for universities to configure structures, resources and incentives to encourage engagement in contract and collaborative research as a means to achieve academic excellence.

These findings suggest that this complementarity is less apparent in basic and social science disciplines. If top quality researchers are not the most active pursuers of industry engagement, then there might be a tension between providing incentives for such activities, and top-level research, meaning universities must find creative ways for managing these different demands. Strategies and policies to promote academics' interactions with industry, universities and policy-makers must be tuned to take account of these differences between academic disciplines. Currently, policy-makers are considering a division of labor among universities whereby some specialize in advanced research and others in business engagement. According to these findings, such an arrangement might be appropriate for some disciplines, but less so for others.

7.6 Conditions for Innovative Collaboration

- Market driven
- Common management
- Clear division of work and responsibility
- Openness (simple IPR rules)
- Room for initiative

7.7 Case Studies

IBM University Programs

IBM implements a host of programs that facilitate interactions with universities, such as fellowships and internships, faculty and research awards, collaborations, student competitions, mentoring programs, executive programs and public-private partnerships. The goal is to recruit the best talent, actively partner with the best research, manage the knowledge created, and re-infuse that knowledge back into the university curriculum.

IBM approach to university relationships: Drawing knowledge, expertise and talent out, feeding support and new knowledge gained back in.

Over the course of many partnerships, IBM has identified some key components of success. It is critically important to have industry executive-level sponsorship. Well constructed memoranda of understanding and IP agreements are also essential. It is important to identify faculty and industry researchers, and subject matter experts to lead the collaborations. IBM experience shows that long-term strategic relationships and goals work best. Ultimately, IBM has found that the consortium construct, involving multiple industry and university partners, leveraging multiple funding sources including government and others, is the most successful.

Deutsche Telekom Laboratories

Deutsche Telekom Group (DTAG) built a University-Industry Collaboration (UIC) by creating a separate organization. This organization consists of R&D personnel both from industry and academia and proves to be effective in channeling innovation potential. Being an organization with its own identity and situated on university premises, the Deutsche Telekom Laboratories (DT Laboratories) offer different ways to overcome the cultural, institutional and operational barriers associated with UIC.

This special form of UIC (i.e., the creation of a separate organization) joins industry and academia in one organisation and one physical site. Building this separate organization is believed to be an especially successful means of overcoming the barriers associated with UIC. The most prominent examples of such organizations have been the Bell Labs or the Microsoft Laboratories in Cambridge (UK).

The organisation of UIC as a separate entity already facilitates the collaboration of industry and academia by creating a common identity with a mutual vision and mission. On top of this, a number of measures to further reduce the barriers of UIC are in place at DT Laboratories which are summarized in Table 5.

Table 5. Solutions of DT laboratories for overcoming the barriers of UIC.

Solutions for Cultural Barriers
• Employment of post-docs that have a natural interest in application-oriented R&D work
• Defined publication and IPR policies
• Collocation, bi-yearly off-sites, one central coffee shop, transparency policy
Solutions for Institutional Barriers
• Organization according to focus of work in strategic research and innovation development
• Clearly defined deliverables, different KPIs in strategic research and innovation development, initial productization or even spin-off support for researchers
• Stability through separated organization with allocated staffing
Solutions for Operational Barriers
• Clear definition of processes
• Coordination through quarterly project reviews and progress presentations
• NIH-Syndrome reduced through mutual projects

Creating a separate organization to engage in an UIC is perceived by the stakeholders as very successful. As a first sign, the explorative potential of the DTAG and technology intelligence has been improved due to the founding of the DT Laboratories resulting in better project selection, increased output of relevant scientific work as well as state-of-the art technical results to be transferred to the operating units of the corporation. The organization has gained reputation as being innovative in itself while producing "fresh" and relevant results both academically and for practical implementation.

8. Bringing the Right Academics in Contact with the Right Industry

Research needs to explore what approaches firms use to establish such partnerships, what interfaces they establish within their R&D and other departments to exploit them and what evaluation measures they put in place. For instance, one can assume that firms differ in terms of their collaboration styles: Some firms might change their partners relatively frequently to adjust the external capabilities to their technology needs, while others might prefer long-term collaboration with the same partners.

The open innovation research agenda suggests the following avenues of enquiry: first, search and match processes preceding university–industry relationships; and secondly, the organization and management of collaboration arrangements (Table 6). On the first issue, search and match processes, the benefit of open innovation for a firm is that specific technology needs can be better matched by searching for external assets or expertise as opposed to generating them internally. However, such benefits will only be realized if firms adopt search routines suitable to match their specific requirements. Research is needed into how such search styles of firms are constituted. Matching rarely occurs as the result of a search involving complete information on the whole range of options available to a firm. Rather, search processes are socially selective in the sense that they are likely to be influenced by existing inter-personal networks and/or previous inter-organizational collaborations, even though screening of the scientific literature appears to be a predictor of university collaboration for firms.

What difference does it make to the search behaviour of firms as to how widely and deeply their research scientists are networked into the scientific community? In this respect, it is an open question as to what types of networks influence firms' search for university partners. Among the potential candidates, there are geographically proximate social networks, 'invisible colleges' or education-related networks such as alumni networks. Furthermore, traded inter-dependencies may dominate in situations where universities act as (lead) users of products which are subsequently commercially developed.

Table 6. Research agenda: university-industry relationships in an open innovation scenario.

• Research and match processes	• Role of networks mechanisms: proximity, invisible colleges, education networks, user-producer relationships.
	• Relationship between precipitating social networks and type of innovative activity/outcome
	• Role of brokers and intermediaries
• Organization and management of relationships	• Variation of individual-level incentives and motivations across different types of university-industry collaboration

	• Variation of organizational models and innovation-relevant outputs. • Firm strategies for exploiting university knowledge in an open innovation scenario. • Impact of institutions on shape, extent and effects of university-industry relationships.

9. Ways of Fostering Academic Freedom while Ensuring Knowledge Transfer

Universities are increasingly being called upon to contribute to economic development and competitiveness and policy-makers have put in place initiatives aimed at increasing the rate of commercialization of university technology. Notably, policy-makers implemented laws that provide commercialization incentives to universities by granting them ownership of intellectual property arising from their research. Other policies encourage universities and firms to engage in partnerships and personnel exchange, for instance via university-industry centres or science parks. Finally, a third type of initiative seeks to build universities' knowledge transfer capabilities by supporting recruitment and training of technology transfer staff.

By actively engaging in technology development, universities are demonstrating ambidexterity in their ability to produce both scientific knowledge and technology outputs. For instance, in rapidly developing areas such as biotechnology, 'star scientists' excel both as academic researchers and academic entrepreneurs. An analysis of the publishing and patenting activities of research-intensive US universities showed a convergence towards a 'hybrid system', linking scientific and technological success. More specifically, it showed that academic success drives technological invention while advantages in technological invention are driven by organizational learning relating to procedures and organizational arrangements for identifying, protecting and managing IP. Over time, positive feedback loops between the two realms lead to a hybrid order where the best universities excel in both scientific research and technology commercialization.

Critics have responded by underlining the potentially detrimental effects of 'entrepreneurial science' on the long-term production of scientific knowledge, voicing fears that academic science is being instrumentalized and even manipulated by industry. Many universities appear to have become 'knowledge businesses' which are focused not so much on generating public goods for national audiences but providing services to specific stakeholders. The perceived risks include a shift from basic research towards more applied topics and less academic freedom, lower levels of research productivity among academics and a slowing-down of open knowledge diffusion.

More specifically, it was shown that in the life sciences, where patents have higher monetary value, researchers patent to enhance their incomes. In the physical sciences, on the other hand, patenting is less attractive because of lower monetary pay-offs and therefore is pursued primarily to develop relationships with firms, access equipment or exploit other research-related opportunities. On the other hand, other studies suggested that working with industry is not necessarily underpinned by entrepreneurial intentions in the sense of responding to economic opportunities. For example, a study of German academic researchers demonstrated that researchers engage in patenting not for personal profit but to signal their achievements and gain reputation amongst their academic and industry-related communities.

The main concern of academics is that industry involvement might restrict academic freedom, i.e. the ability to pursue curiosity-driven research without having to consider commercial gain. However, academics appear to draw boundaries between the forms of industry engagement they see as legitimate, and others, that they view as overly commercial. In any case, academics express significant support for industry collaboration particularly when it is related to their research. A meta-study shows that academic researchers' attitudes to financial ties with industry sponsors are largely positive, especially when funding is indirectly related to their research, disclosure is agreed upfront, and ideas are freely publicized. A study of German academic researchers in four disciplines suggests that acquiring additional research funds and learning from industry constitute the main motives for engaging with industry.

Strong IP policies pursued by universities may reduce the incentive for firms to commercialize inventions resulting from UIC collaborations.

10. Practical Solutions and Areas that need to be Strengthened

The problem of academia-industry collaboration has been the topic of a thesis (E.S. Calder, "Best practices for University-Industry Collaboration", MIT, USA, 2007). Even though the US model cannot be strictly applied to European projects and consortia, some findings are worth mentioning:

It appears that the presence of ***"boundary agents"*** in companies facilitate the technology transfer. These individuals are in charge of collecting external information, identifying new projects at academia that could affect company products and/or processes. The "boundary agents" translate the information for internal use and could impact academic projects so that these projects best fit the industry objectives and market development policy.

A ***long-term collaboration*** is generally much more beneficial to both parties than a short-term collaboration. On the one hand, industry could adjust policies, training, and business practices to promote sustainable collaborations with research. On the other hand, research organizations could offer more options for training and networking with people in charge of negotiating such collaborations. The European Union has already implemented such exchanges through Marie Curie research networks.

Geographic separation between collaborating university and industry was found to have no effect on the outcomes and impact of the collaborative project. This is an excellent point for ***multinational European consortia***.

A project is more likely to be successful if it complements other internal research and development activities of the company and if university researchers have a broad understanding of the company's strategy and other R&D activities. This can be achieved through the ***participation of university researchers in meetings with professionals from business units***.

Obviously, ***clear mutual understanding*** of project's goals and methods is an absolute requirement.

A number of common key factors or best practice elements for the effective organisation and management of university-industry research partnerships have been identified in the literature including:

Table 7. Areas that need to be strengthened.

- Improve innovation strategy and management in academia
- Incentives
- Research centres that are industrially focused
- Bring market expertise to a project from the beginning
- Mobility between companies and universities / institutes / research centres
- Phased collaborations to build trust
- Plug and play models – flexibility in entering and leaving projects
- Reduced bureaucracy and quick turnaround – success of innovation vouchers across Europe
- Greater project management focus on implementation of results and impact
- Assessment by independent market expert
- Financial commitment by the company
- Top up funding for projects with potential impact
- Frequent meetings and seminars between researchers from industry and academia
- Establishing teams on focused topics
- Establishing a annual funds from the industry to academic institutes. Setting-up, by the government, special funds for encouraging such collaboration.
- Working with industry will be a parameter in academic promotion
- With respect to IP issues, simple contracts and benefits for the researchers.
- Difference in working culture and behaviour; is academic nature suitable for collaboration with industry?
- Duration of research and development. Promised schedule, tasks and deliverables (prototype not papers).
- Commitment of partners. Building trust between the partners.

- Regional Centres for Industrial Collaboration.
- Mutual trust and good personal relationships that develop over time.
- Good project management (e.g., process monitoring, effective communication).
- Mutual understanding of motivations, interests and needs (organization missions).
- Clearly specified objectives and expectations.
- Frequent, clear and open communication and feedback.
- Commitment and continuity of both partners – helped by mutual goals and benefits.
- Close alignment of expertise and interests of parties.
- Agreements on publication issues, roles and responsibilities.

10.1 Recommendations to Help Spur a Robust Partnership

Develop metrics to measure the success of economic development decisions. This will allow stakeholders to base future decisions on potential return on investment (rather than primarily on geographical or political considerations)

Flip the model for the way universities pursue industry partnerships. Currently, universities seek an industry partner for commercialization after a product or process is discovered. Instead, clusters of industry should pull relevant research from universities by jointly identifying and communicating their needs for pre-competitive research.

As community members, universities need to invest their own resources in building regional innovation systems, for example using endowment investment income to fund seed grants that bridge the gap between early development and commercialization.

Finally, strengthen the connection between innovation assets throughout the country and the country's venture capital investors.

10.2 How Some of the Leading Research Universities in America Established and Maintained Partnerships with Industry?

A paradigm model was developed that portrayed the interrelationships of the axial coding categories by using the following headings: causal conditions, phenomenon, context, intervening conditions, strategies and consequences (Figure 3).

It was shown that in order to establish and maintain mutually beneficial relationships with industry, universities must proactively manage their relationships with industry, putting processes and organizational structures in place to reduce or eliminate risks while maximizing the benefits to both industry and themselves. Regardless of the type of organizational structures and processes universities employed, recognizing the importance of industry partnerships to their overall bottom line was of primary importance.

Ultimately, a process theory was developed for university industry partnerships. This process theory, which is depicted in Figure 4, described how the research universities surveyed established and maintained mutually beneficial partnerships with industry. The process steps identified did not necessarily all occur in a specific order for everyone, but they provided a framework for understanding the process of establishing and maintaining partnerships with industry at research universities.

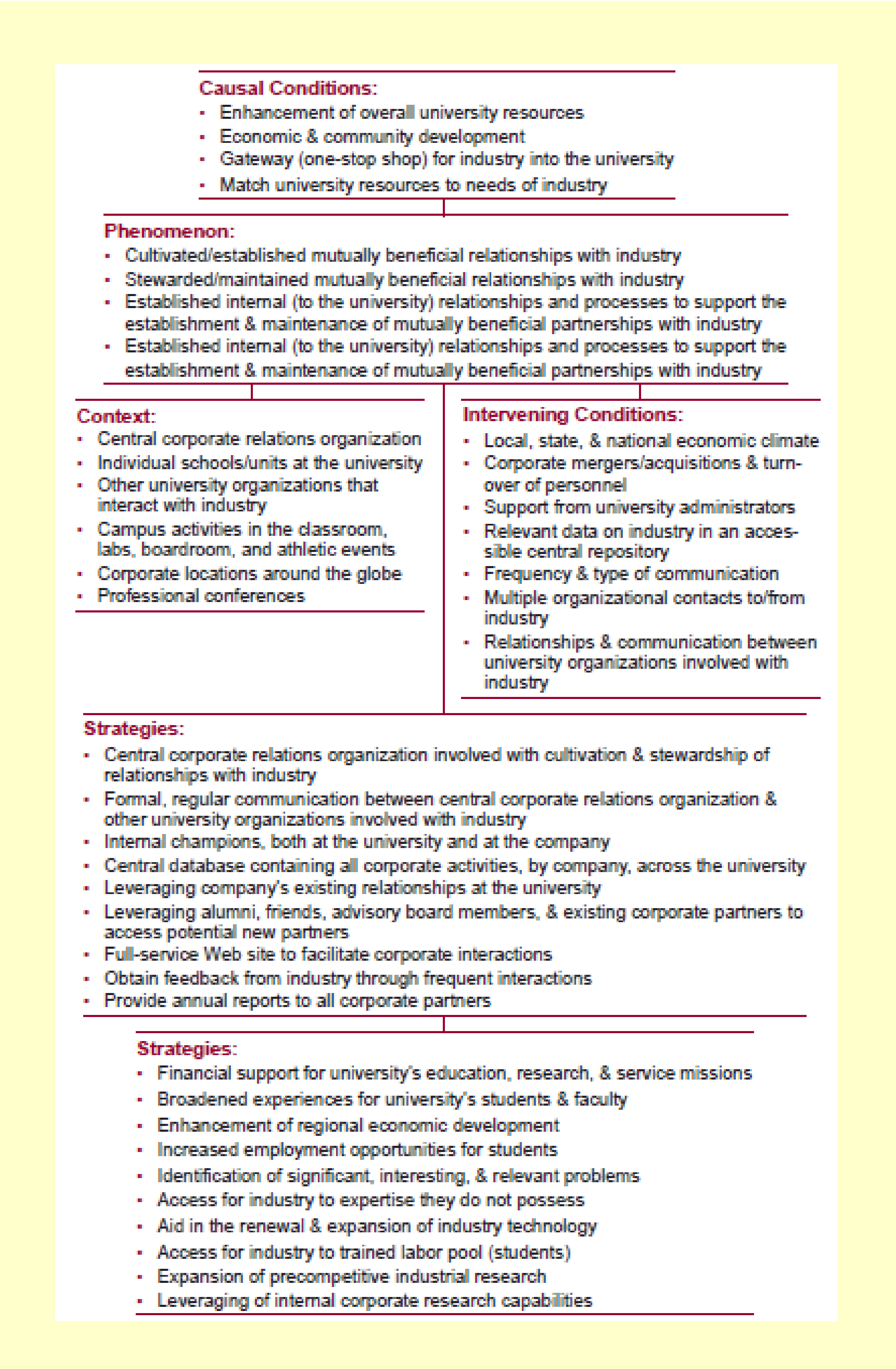


Figure 3: University-industry partnership paradigm.

Analysis of this process revealed that the universities did not use a "one size fits all" approach to establish and maintain successful partnerships with industry. However, a set of theoretical propositions generated from the data describe what appear to be successful practices at some of the nation's top research universities. These practices could be modeled at other institutions if appropriate. If managed properly, the establishment and maintenance of mutually beneficial university- industry partnerships can be a win-win-win for the university, for industry, and for society.

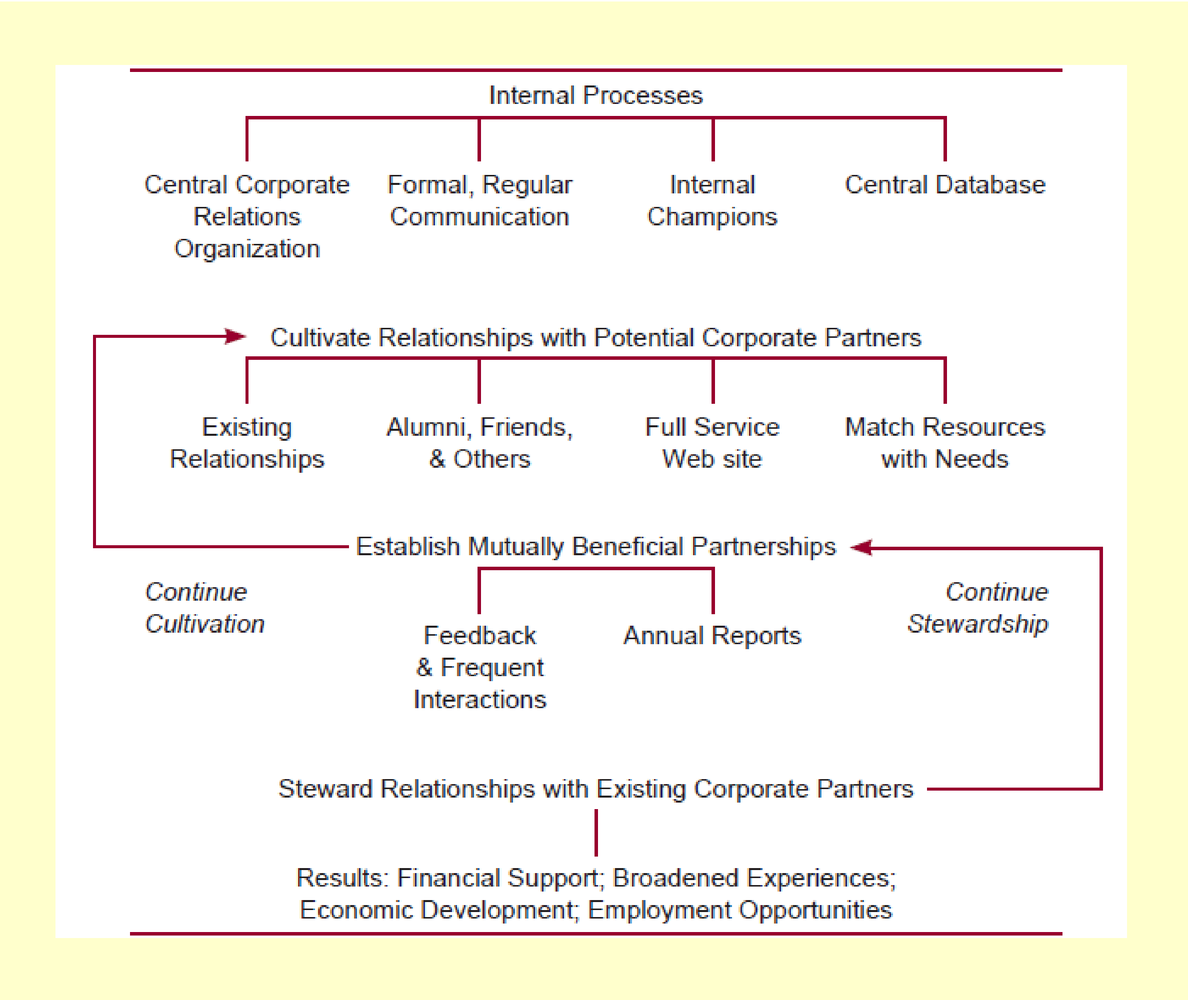


Figure 4: University-industry partnership process.

10.3 Good Practice Model

Figure 5 shows a good practice model which includes all the factors found to have had a significant impact on the perceived success of case study projects (organised into six key areas).

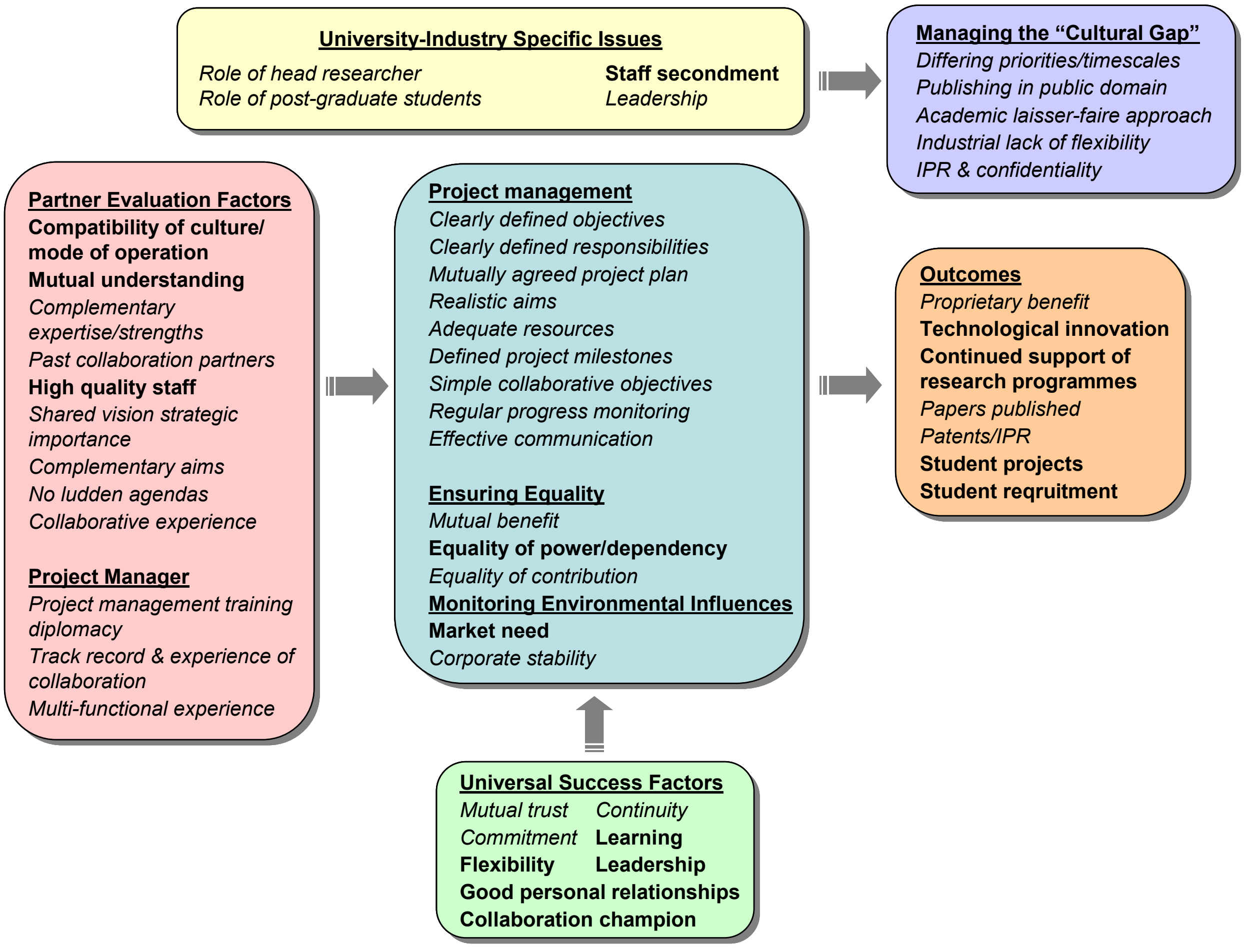


Figure 5: Good practice model for the effective management of collaboration.

10.4 Implementing University Collaboration Strategies through Portfolio Management

Various researches indicate that UIC portfolio management involves the strategic alignment of UIC projects and the organization and formalization of UIC management during initiation, realization, and transfer phases of collaborative research projects. Furthermore, it has been shown that different collaboration strategies require different portfolio management approaches. While exploitation and ambidextrous strategies require higher levels of formalization and centralized coordination, pure exploration strategies seem to be most effective when managed decentralized.

Overall, research results suggest that proper portfolio management of UIC activities is very important. In a recent study, crucial elements of UIC portfolio management were identified and subsequently used to develop a conceptual framework of UIC portfolio management that outlines the implementation of UIC strategies, thus showing how companies can implement UIC portfolio management through strategic alignment, formalization, and an organizational structure. In addition, the link between UIC strategy and portfolio management activities was analyzed revealing that different strategies require different implementations of portfolio management.

Table 8 presents the proposed framework to implement UIC portfolio management.

Table 8. Implementation of UIC Portfolio Management.

UIC Strategy[a]	Strategic Alignment[b]	Organization[c]	Formalization[d]
Exploration Strategy	medium	decentralized joint or endowed research	low
Exploitation Strategy	medium	centralized contract research	medium
Ambidextrous Strategy	high	centralized various types	high

[a] While exploration strategies are targeted towards the generation of new knowledge and capabilities in order to achieve long-term success, exploitation strategies focus on the valorization of existing knowledge and short-term results. An ambidextrous strategy is the combination of both strategies that yields to the exploration of new and the exploitation of existing knowledge.

[b] Strategic alignment may be achieved via goal clarity, top management support, integration of UIC activities into internal NPD, long-term commitment, and a global UIC strategy.

[c] When shaping the organizational structure of UIC, companies may install centralized departments that manage the collaboration portfolio and deliberately structure the portfolio by choosing a mix of different collaboration forms.

[d] The formalization of UIC involves a standardized partner selection, project initiation, execution and evaluation, as well as a dedicated technology transfer process.

11. Suitable Funding Instruments and Boundary Conditions that could Enhance the Links between Academia and Industry (at both EU and National Levels)

11.1 EU level

A necessary starting point is the creation of appropriate conditions for a dialogue between academia and industry and for the clear expression of needs and strategy (on the company side) and of ideas, projects and preliminary findings (on the academia side). Below is a non-exhaustive list of existing platforms/strucures where people from academia and industry are supposed to meet and exchange relative information.

European Technology Platforms (ETPs): Gather actors form the same sector and from both industry and academia with similar interest and objectives. Even though the participants to an ETP jointly define their common needs for the years to come via strategic research agendas (SRAs), they do not seem to use ETP as a network to find a partner or initiate collaborative research.

Joint Technology Initiatives (JTIs): Strongly orieneted towards industrial interests, researchers from academia may not be sufficiently involved.

European Institute of Innovation and Technology (EIT): Gather actors from higher education, research and business sectors. It is claimed that EIT should strengthen "the links between the sides of the knowledge triangle" and, as a consequence, EIT should also strengthen the links between research and industry, accelerating the transfer of knowledge and innovation to market. EIt is relatively new and the impact of EIT on academia-industry relationships is still to be evaluated.

Innovation Relay Centres (IRCs): Created in order to facilitate the transfer of innovative technologies to and from European companies of research departments. IRCs should be the places where research labs and industry (mainly SMEs) can find an appropriate partner, at least in the same region/country.

Brokerage Events: Organized (by IRCs, professional societies/associations,..) to help with the preparation of proposals and the search for the right consortium partners. Participants can present their ideas to potential project partners, look for project ideas or consortia to join, build a consortium. Theoretically, these events are the ideal platforms for identifying possible new partners and for initiating the dialogue. They are generally successful and well attended. The counterpart is that these events are sometimes too well attended (in the hope to gather the perfect consortium within a single day) and it becomes difficult and time-consuming to find the right partner(s) in the crowd. Multiple and smaller events on targeted topics (e.g., the topics of the Calls for Proposals) may be more effective. Costs for attendees may be reduced if the EC sponsors this type of meetings.

Dedicated national and European workshops: It can be taken advantage of these workshops to include small brokerage events. However, the participation of people from industry is generally limited and therefore the impact on academia-university relationships may be low.

Marie Curie research networks and Marie Curie fellowships: These networks and fellowships interconnecting different research labs in university and industry with exchange of students/young researchers are an excellent basis to give the new generation of researchers a "double" culture and to act as "boundary agents" in a company later on. Even though the outcomes of research projects may not be directly marketable, the impact on the university-industry relationships should be important, thus setting the scene for long-term collaboration.

Structures/platforms for discussion, exchange of information and collaboration between academia and industry do exist at the European level. However, they do not seem to be adequately efficient. Is it simply because partners from both sides do not find personal interest in collaborating? To which extent should the human factor be considered?

A non-exhaustive (by far) tentative list of measures is proposed below:

- Organize and support multiple targeted small/medium brokerage events
- Heavily promote all opportunities for bilateral university/academia-industry meetings
- Heavily promote EIT's results and advantages for industry
- Disclose the Workprogrammes and Calls for Proposals in their draft forms (i.e. before the official publication); call for Expression of Interest (EoI) in synergy with the National Contact Points (NCPs) and IRCs so that potential proposers can find (well in advance) appropriate partners through NCPs, IRCs, meetings, workshops and brokerage events.

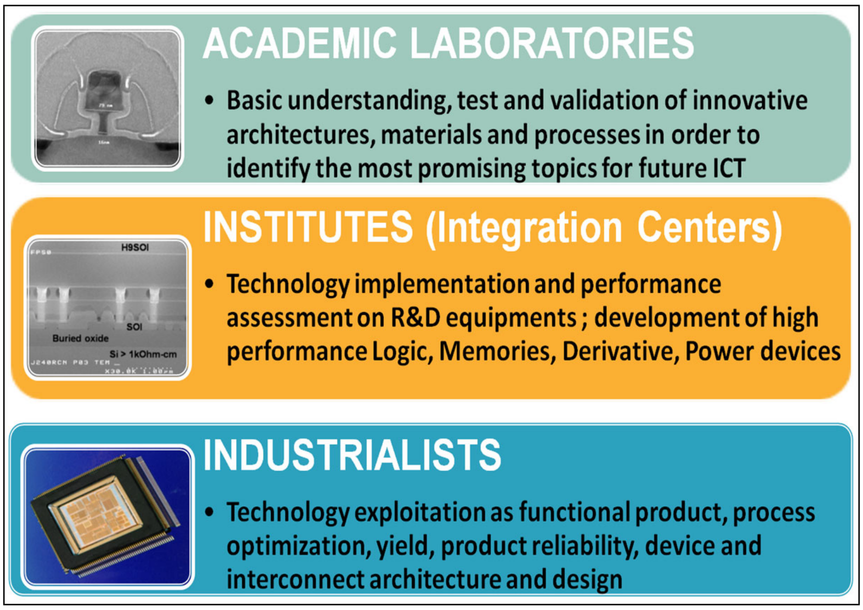
- Network the NCPs and IRCs for efficient and fast dissemination of the EoI over the EU.

- Define metrics assessing the impact of brokerage events and the efficiency of NCP and IRC networks.

- Study the feasibility of building a federation of European Centres of Industrial Collaboration (ECICs) aligned with regional industries, market sectors and academic strengths to spread best practice. Such an organization could align with regional, national and European networks and technology platforms, etc. It also could leverage the combined strengths of the ECICs to access additional support from European Union, industry and private or venture capital sources to serve both SMEs and industrial partners in their local economies to drive innovation across Europe by operating as a coherent managed European Network.

- Development of multi-disciplinary research infrastructures to improve the innovation cycle by closing the gap between advanced research and industrial needs.

- A successful innovative infrastructure (e.g., European Nanoelectronics Infrastructure for Innovation, ENI2) should rely to a three R&D level organization.



- Super-national cooperation is needed. Member States tend to fund University/PRO only when national industry is involved, which is detrimental to building European excellence centres especially in small countries. Moreover, programs like EUREKA, JU and PPP with strong national participation tend to favour short term application development rather than long term technology (or design) development. What could be useful is something like ERC, but driven by industry or ETPs for what concerns the selection of themes and projects. Funding should be provided for cross-boundary research activities where there is a clear "market failure" for what concerns funding by single Member States.

- Direct industry-university cooperation could be covered by usual FP7 type projects (research or Marie Curie) if the cooperation involves more companies along the supply chain. Also what is done in some countries about tax incentives for contributions given to Universities could be pushed as European standard.

- Aggregation of universities at European level could help provide SMEs with an easier access to a wider source of expertise. European money could go to universities setting up this kind of support organizations.

- When SMEs can start thinking of European projects, open calls for SMEs on wider topics should be provided.

- IP ownership is a hot issue and discussions among companies and universities normally delay a lot the conclusion of Project Agreements. The Commission should not over-regulate: when there is a direct research contract, it should let the parties agree on the conditions. However, some clearer rules are needed when partners receive European funding. The solution could be that, in case of joint development of the IP, the industrial partner receives a free license for use, but without sublicensing and exclusivity rights. The latter can be bought at a reasonable discriminatory price if the IP proves to have commercial value.

11.2 National level

France

The ***Fonds Unique Interministériel (FUI)***, launched in 2004, is a programme supporting applied research on and development of new products and services marketable on the short time scale. Amongst the different initiatives included in FUI, let's quote:

Pôles de Compétitivité: In a designated region, a *Pôle* is a cluster gathering actors from higher education, public and private research labs, and industry (including SMEs) with a common development strategy in synergy with the global development strategy of the region. These clusters are intended to strengthen the partnerships between academia and industry within a particular region and they should focus on technologies with short market growth.

Sociétés d'Accélération du Transfert de Technologies (SATTs) or Technology Transfer Acceleration Firms: The role of the SATTs will be to boost the business development of the most promising research projects, to significantly improve the effectiveness of technology transfer, and to generate more value. The first call for proposals just closed at the end of 2010 and results are not known yet.

Label EIP (Enterprise Innovante des Pôles): Created in 2010, the goal of the EIP programme is to help innovative SMEs (and start-ups) involved in R&D and member of a *Pôle de Compétitivité* to get recognition and to find private and/or public investors.

Agence Nationale de la Recherche (ANR): ANR regularly launches calls for projects on different topics. The principle of ANR projects is very similar to European projects with different degrees of industrial involvement.

United Kingdom

Yorkshire Forward regional development agency created a scheme called Centres of Industrial Collaboration (CIC) which was designed to support SMEs. CICs were professionally managed centres in Universities that undertook services for companies at commercial rates. The funding scheme was competitive and only centres that were embedded in world leading research groups and who had a clearly identified industrial need/market for their services were funded and awarded CIC status. The funding was limited to three years and thereafter CICs were expected to generate their own commercial revenues to survive. The responsiveness of CICs and regional delivery was particularly suitable for supporting SMEs.

Whilst the CIC scheme may not appear "game changing", as it simply provides services for industry, it has made global, national and regional impact, and whilst some CICs have closed, a number still remain and continue to thrive in areas such as particle technology, biomaterials and tissue engineering, materials and pharmaceuticals. Since 2003 (the start of the CIC scheme) there has been a great deal of interest in the CIC programme with visits from companies, governments, funding bodies and universities from Europe, Middle East, Asia, Australia and USA. The CIC programme was highly successful and received a major European award for "Technology Transfer from Research Institutes to SMEs" (RegioStars 2008).

The CIC programme was successful because:

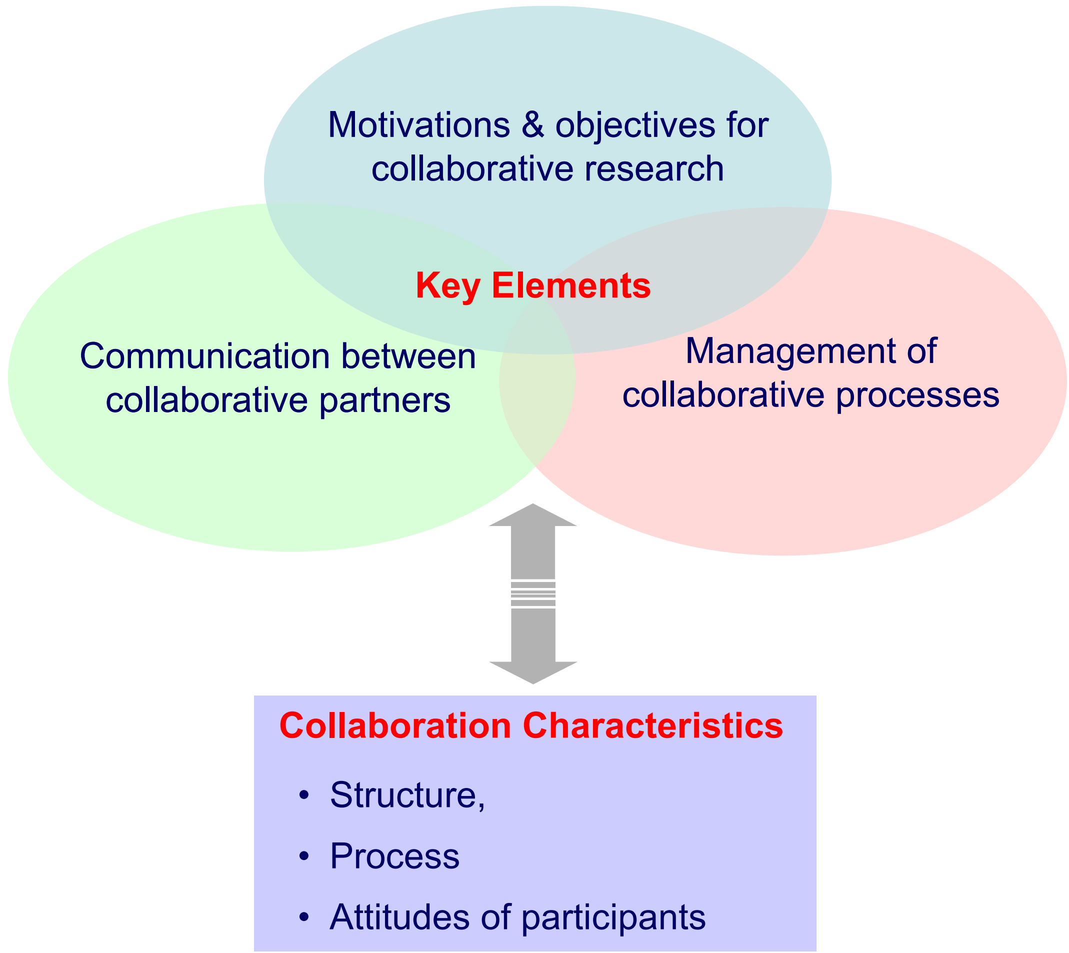
- It was market led (therefore companies pay commercial rates for services)
- CICs were intimately embedded in leading research groups with critical mass and state of the art facilities (access to expertise and facilitites)
- The CICs had a business plan and were professionally managed with a fulltime commercial manager/director (delivery on time to budget at desired quality)
- Fulltime technical, research and administrative staff (not distracted by teaching and academic research duties)
- They had access to real technology and innovation rather than simply being a signposting organization
- Own laboratories for contract research, testing and open access.
- Although aimed at regional SMEs, successful CICs were not constrained by regional and national boundaries and worked with companies of all sizes from around the world.

12. Conclusions

The industry-academia collaboration is characterized by a complex, multifaceted nature and its effectiveness depends partially on the following three key elements:

- Motivations & objectives for collaborative research
- Communication between collaborative partners
- Management of collaborative processes

These three elements are individually complicated (i.e., strongly dependent on collaboration characteristics such as structure, process and attitudes of participants) and interactive and their effects are interdependent.



Motivations & Objectives for Collaborative Research

There exist a wide variety of motivations for industry-academia collaboration relate to the individual and organizational cultures of the participants.

The motivations are also influenced by external factors such as the decline in funding from government which has driven academics to find other sources of finance and an increasingly competitive market which has forced industry to search for new ideas or knowledge from universities to sustain future profitability.

There exist also a variety of perspectives towards collaboration which are also related to the different cultures, attitudes and interests of the participants.

The different motivations and objectives of industrialists and academics can be correlated with the effectiveness of collaboration (e.g., delay of negotiations at the start of a collaborative relationship where attempts are being made to try and meet the different needs and expectations of the participants).

The needs of both sides should be balanced to ensure that the two parties achieve mutual benefit from collaboration. Failure to achieve such a balance could lead to low enthusiasm and a subsequently unsatisfactory relationship. Poor clarification of motivations or objectives at the outset can lead to unrealistic expectations and misunderstandings.

Communication between Collaborative Partners

Communication problems can arise between industrial and academic collaborative participants as a result of their disciplinary backgrounds.

The compatibility of the participants' backgrounds can significantly influence the perceived success of collaboration. However, further research needs to be carried out to explore how variations in the educational qualifications and professional disciplines (e.g., engineer, manager, scientist, etc.) of industrial and academic participants influence collaboration effectiveness.

Another common cause of ineffective communication and knowledge transfer in collaborations is industry's concern for confidentiality. Some industrial partners do not believe academics can be trusted because of their preference for open communication.

Management of Collaborative Processes

It is evident that because no two collaborations are the same in terms of motivations, objectives, structure, process, outcomes, type of participants, etc. it is not easy to state what the appropriate management strategies are for effective industry-academia research collaborations. There are however a number of research findings regarding best practice in the management of collaborative research that can be deemed generic. These include the following:

Adaptable management approach because industry-academia collaborative research is prone to unexpected developments, changes and outcomes, particularly if the research is curiosity-driven.

Appropriate mechanisms for the establishment of development stages of collaborative research to ensure that the motivations and objectives for collaboration are clarified between all participants, that there is good communication (i.e., regular meetings) and mutual understanding between the participants, and that agreements are set up to sort out issues such as intellectual property and confidentiality.

According to the above, it is of paramount importance to discover ways of balancing the competing objectives and sources of conflict within collaborating teams, identify effective communication formats and provide guidance on the management of industry-academia research collaborations.

In relation to the future of industry-academia collaborative research, the evidence indicates that future collaborations may become more successful because of growing mutual understanding and awareness between industry and academia, and also due to an increase in collaborative experience. Changes in individual and organizational attitudes or cultures resulting from increased collaboration may however create serious problems in the future. There is evidence that some academics are becoming more business focused and paced as a result of collaborating with industry. Learning from collaboration brings about changes in awareness, understanding, behaviour and beliefs, and there is a risk that learning from each other can lead to the participants (individual / organizational) becoming more similar in their ideas and ways. This could result in a reduction in the quality of academic research and also in novel insights, which could create problems for innovation. Measures therefore need to be taken to ensure that the basic missions or working practices of the participants are not altered. Collaborative schemes that take into account both basic and applied research, and support quality research over more flexible and longer timescales will be shown to be valuable.

References

D'Este, P., Perkmann, M., Why Do Academics Engage with Industry? The Entrepreneurial University and Individual Motivations, J. Technol. Transf., February 2010.

Perkmann, M., King, Z., Pavelin, S., Enganging Excellence? Effects of Faculty Quality on University Engagement with Industry, Research Policy, 2011.

Perkmann, M., Walsh, K., University-Industry Relationships and Open Innovation: Towards a Research Agenda, International Journal of Management Reviews, 9(4), 259-280 (2007).

Dunowski, J.-P., Schultz, C., Kock, A., Gemunden, H.G., Salomo, S., Implementing University Collaboration Strategies Through Portfolio Management, Paper presented at the Summer Conference 2010 on "Opening Up Innovation: Strategy, Organization and Technology" at Imperial College London Business School, June 16-18, 2010.

Prigge, G.W., Torraco, R.J., University-Industry Partnerships: A Study of How Top American Research Universities Establish and Maintain Successful Partnerships, Journal of Higher Education Outreach and Engagement, 11(2), 89 (2006).

Rohrbeck, R., Rohrbeck, A., Heinrich, M., Making University-Industry Collaboration Work – A Case Study on the Deutsche Telekom Laboratories Contrasted with Findings in Literature, Munich Personal RePEc Archive (MPRA) Paper No. 5470, November 2007.

Bodas Freitas, I.M., Geuna A., Rossi, F., University-Industry Interactions: The Unresolved Puzzle, Working Paper No. 09/2010, Working Paper Series, Department of Economics "S. Cognetti de Martiis", Università di Torino.

Czarnitzki, D., Hussinger, K., Schneider, C., The Nexus Between Science and Industry: Evidence from Faculty Inventions, Faculty of Business and Economics, Katholieke Universiteit Leuven, 2009.

Butcher, J., Industry-Academia Research Collaboration; Characterising Structure, Process & Attitudes in Support of Best Practice, PhD Thesis, Cranfield University, 2005.

Improving Knowledge Transfer Between Research Institutions and Industry Acroos Europe, Communication from The Commission, 2007.

Skorton, D.J., Heylen, S., Weyhenmeyer, J.A., LaFleche, S.P., Ezbiansky Pavese, K., Baston, R. Academic-Industry Collaboration: Best Practices, Presented by Johnson & Johnson and The New York Academy of Sciences, December 2009.

Design Research in University-Industry Collaborative Innovation: Experiences and Perspectives, D. The Early Stages of New Product Development, Arnold, H., et al., (Eds.), Applied Technology and Innovation Management, 2010.

Heaney, M.B., Williams, J.C., Mazauric, V., University-Industry Interactions: Some Industrial Scientists' Perspectives, Journal of Computer-Aided Materials Design, 3, 65-70 (1996).

II. Best Practice in Innovation

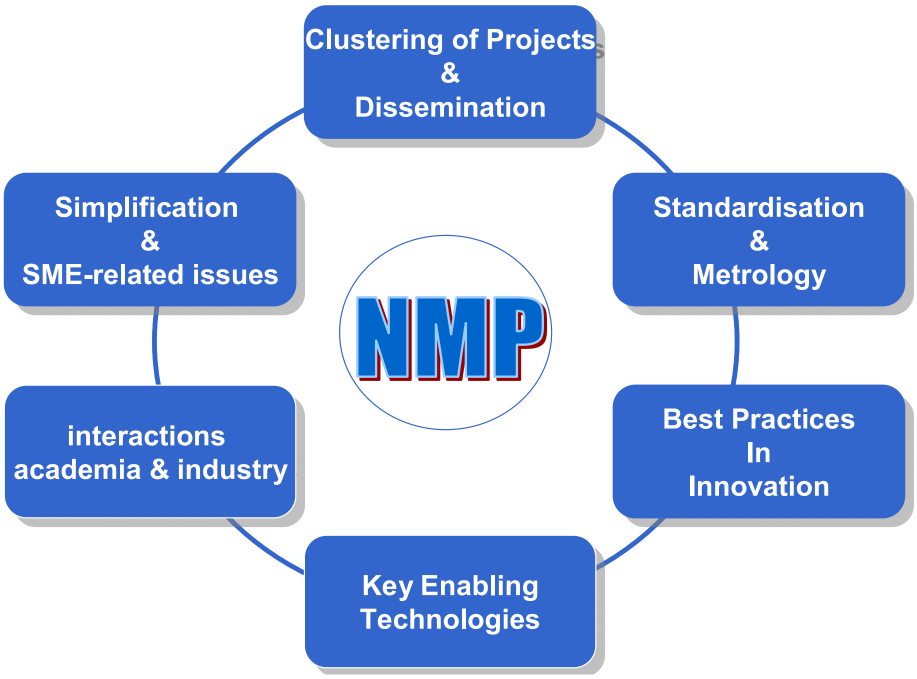
Marie-Isabelle Baraton, Leah Boehm, Costas Kiparissides, Hans Hofstraat, Francois Mudry, Jens Neugebauer, Klaus Sommer and Terry Wilkins (Rapporteur)

Supported by Nicholas Deliyanakis, Anne Maillaband and Nathalie van Neck (European Commission)

Preface

Following on from the Expert Advisory Group's (EAG) Mid-term review[i] of NMP's FP7 programme, the Group held a 2 day workshop 4-5 Nov 2010 to establish areas where practical steps could be identified for substantial improvement in the pace and quality of the economic and social impact, through the uptake of nano-, materials- and production- technologies, in Europe's manufacturing industries. The Group identified 6 such areas below:

Focus for Improving Return on Investment from EU Funded Research and Innovation



The EAG agreed to prepare an orientation paper for each of the topics above. All 6 subjects were viewed as equally important and mutually synergistic for achieving the required future impact. Working groups were established from within the Group's membership, supported by staff from the NMP and other Directorates to prepare an orientation paper for each subject.

OECD Definition of Innovation
"Innovation consists of all the scientific, technical, commercial and financial steps necessary for the successful development and marketing of new or improved manufactured ***products****, the commercial use of new or improved* ***processes*** *or the introduction of a new approach to a* ***social service****.*

1. Terms of Reference

The "Best Practice in Innovation" sub-group of the EAG was established, to prepare an orientation paper for the Commission following the 2-day workshop 4-5 Nov 2010. Two significant contextual factors were taken into account in the preparation of the paper. The first is the highly dynamic and continuing difficult global economic precipitated by the crisis in the banking and finance sector in 2008. The second is the high-level research and innovation policy development taking place within the European Commission, European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions as it progresses plans towards its Europe 2020 vision. Within the latter, NMP has a primary role in the delivery of the "Innovation Union" flagship initiative" in turn will strongly support two further flagship initiatives, namely "Industrial Policy for the Globalisation Era" and "Agenda for New Skills and Jobs". The terms of reference for the team preparing this paper are as follows:

- There is a gap between the end results of most projects, even those concentrating on applications, and developing successful products and services. **[Death Valley problem]***

- This gap can be partially bridged by funding demonstration and other innovation-related activities (a complete bridging using public funding alone would be impossible). The purpose of this paper is to look at innovation-related issues that can or should be addressed in the research cycle, identifying costs where appropriate.

- The paper should propose funding mechanisms, specific elements in existing mechanisms, and other measures (e.g. support actions) that could be used to address these innovation-related issues. It may build on best practices at the EU and national levels.

- The paper should be framed in two relevant Europe 2020 flagship initiatives: Innovation Union (COM (2010)546); and An Integrated Industrial Policy for the Globalisation Era putting Competitiveness and Sustainability at Centre Stage (COM (2010)614).

In addition to the above reference documents the Green paper From Challenges to Opportunities: Towards a Common Strategic Framework for EU Research and Innovation Funding (COM (2011) 48 was also taken into account. Launched the public consultation process and is a logical extension of the previous two papers and together the 3 documents form an innovation policy set. The analyses and recommendation from the set were summarised by the European Commission's President M Barroso's presentation to the European Council on the Innovation Priorities for Europe, 4 Feb 2011.

From the terms of reference and background policy publications, the following deliverables for this orientation paper were derived**:**

- Orientation paper not an in-depth study
- Best practice in innovation (what works) & quantitative indicators
- Practical approaches to help improve the state of the art
- Practical measures to create a common EIA (European Innovation Area)
- Areas where more detailed work is needed plus ways to deliver it

The EAG elected to factor in the continuing difficult economic climate and the requirement by both member states and the EU to ensure best use of funds through programme synergy. The focus of this paper is to provide maximum support to for large industry and SMEs in the Innovation Union flagship initiatives for Europe 2020. Grand challenges are dealt with elsewhere and are not part of this paper. Arguably, the best way to accelerate progress with these is through greater success of its industrial companies and SMEs.

2. Europe 2020 -Innovation Union 10-Point Action Plan

From the reference documents and President Barroso's presentation the following action plan emerges:

1. Invest in Education, R&D, Innovation and ICT
2. Tackle fragmentation, EU and national research and innovation systems
3. More world class universities and attract top talent from abroad
4. ERA for researchers and innovators complete in 4 years
5. Simplify access to EU Programmes

- *Enhance leverage of private sector and EIB funds*
- *ERC role should be enhanced*
- *FPs support to SMEs must be boosted*
- *ERDF should be used to boost research & innovation capacity across Europe*

6. Closer cooperation between Science & Business must be enhanced
7. Remover barriers for Entrepreneurs

- *Access to finance for SMEs*
- *Affordable IP*

- *Faster/better standards setting*
- *Strategic use of EU procurement budgets*

8. Launch European Innovation partnerships to accelerate innovation & tackle grand challenges

9. Better exploitation of Europe's design and creativity (Inc. public sector)

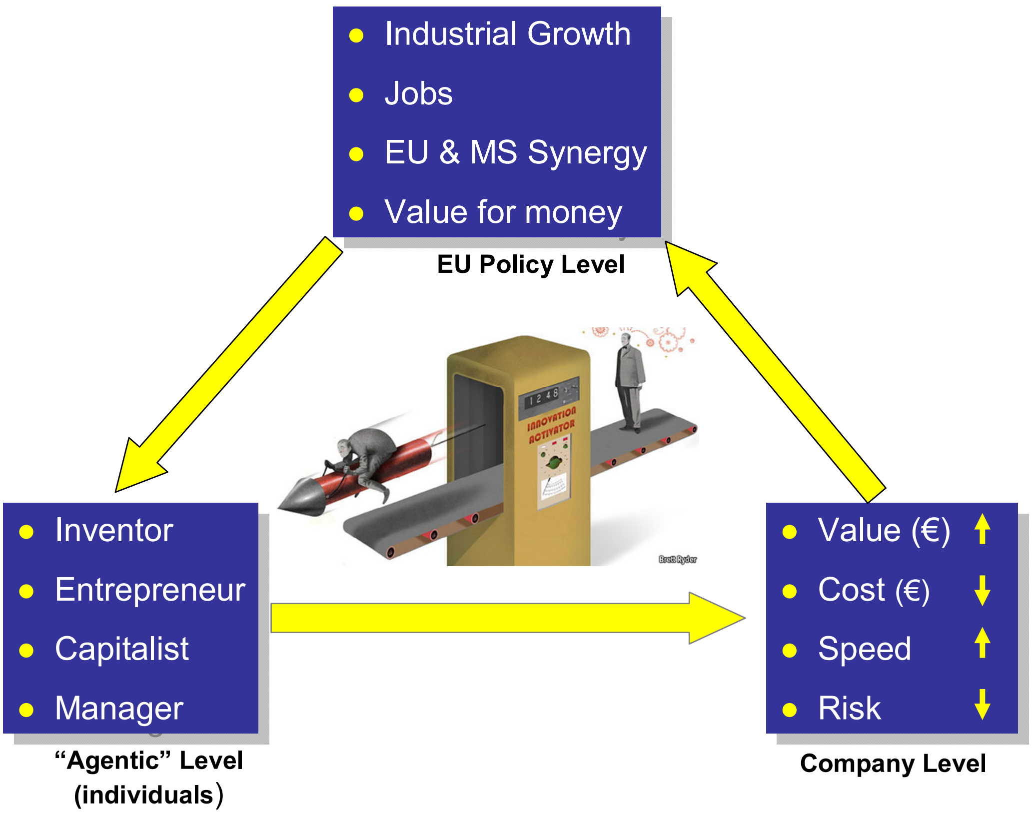
10. Better collaboration with international partners (C.f. Open Innovation)

This orientation paper addresses points 2, 4 5, 6, 8 and 10 directly. Other action points are dealt with by the EAG's other 5 orientation papers. .

3. Who Delivers Innovation?

According to Schumpeter[ii], entrepreneurs drive disturbance of stationary state economic cycles and cause economic development through innovation. This paper examines innovation processes at 3 levels where actors working interact to have a critical impact on the success of the whole innovation ecosystem within which they co-exist (Figure 1):

Figure 1 3-Level Innovation Ecosystem and its Actors



Innovation, whether by products, processes or services, is delivered at the primary level by individuals (Agentic Level). The 4 actors or roles described, namely the ***inventor, entrepreneur, capitalist and manager,*** are at the core of all innovations.

At the next level up, companies create innovative organisations to support the primary agents. Their objectives are to develop and grow their respective businesses through innovations in products, processes and services. But to be truly competitive their business innovation processes must maximise financial returns and speed to market whilst minimising costs and business risks of their innovation processes. To achieve these objectives they recruit, develop staff with these competences. In some companies, particularly SMEs some individuals are capable of operating at a high level in more than one of the 4 roles.

At the tertiary levels, actors at the EU and member states policy level seek to maximise growth, jobs, synergy between the EU and member states and value for taxpayers' money. The 3 innovation levels (agentic, company and policy) are also known as micro-, meso- and macro-levels in the socioeconomic literature.

An integrated European innovation system needs to develop individuals in the 4 agentic roles and arm them to innovate and develop new businesses or socially beneficial services that are globally competitive.

4. Initial Scan of Best Practice

To stimulate the successful translation from it is essential to bring together industry and academia in an active way. The conventional, linear, model of interaction between academia as 'knowledge provider' and industry as passive 'knowledge buyer' in general does not lead to successful innovations. The Dutch Centre for Translational Molecular Medicine (CTMM, see www.ctmm.nl) is an example of a Public-Private Partnership in which industry (SME's and large companies) contributes through in-kind participation, by contributing researchers that work side-by-side with academic researchers in the projects. Participation of clinicians and of societies that represent patient groups provides excellent boundary conditions to ensure the development of meaningful innovations in healthcare.

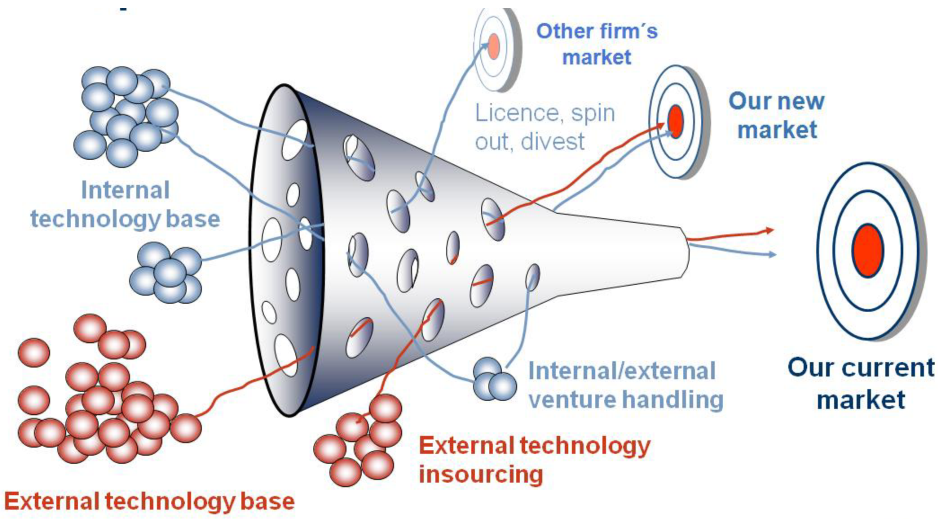
During the last decade there has been a growing recognition the importance of open innovation, particularly by large manufacturing companies operating in fields where the pace of emergent technology generation is fast. There are always more ideas and technologies created outside an organization than within. Hence, the challenge is to find ways to access the best and most relevant for you organization. Application of learning from the Guidelines for Successful Open Innovation as published in the Handbook on Responsible Partnering (see www.responsible-partnering.org), ensures optimal preparation and execution of Open Innovation projects. An approach to generation and exploitation of Intellectual Property is presented, which provides adequate rewards to all contributors. Suggestions are made for effective implementation routes, engaging all stakeholders, but also taking advantage of novel business models and alliances.

Many examples of modern good practice have been observed across the European Union and beyond. The majority have been based on open innovation and in a sense from FP6 through the creation of the European technology platforms (ETPs), joint technology initiatives (JTIs) and more recently in FP7 the public :private partnerships (PPPs), Europe has been creating an environment wherein open innovation eco systems would be encouraged. Section-5 below, describes the theory of open innovation and 3 types of models of emerging best practice in Europe

5. From Open Innovation to Co-Creation

The basic concept of open innovation has been described by Chesbrough et al[iii]. It describes a classical innovation funnel of ideas to development to commercialisation modified to enable technology, intellectual property (IP), processes and products to be and to be in-sourced or to be licensed out as IP or in spin-out companies.

Figure 2 Classical Open Innovation Model



Many leading EU and US multinational companies have developed open innovation models within their strategic plan and management systems. It is seen by leading pharmaceutical companies as a means of accessing more and better ideas and IP for new active pharmaceutical ingredients (APIs) at a time when the cost discovery of classical crystalline small molecule drugs is soaring but the success rate through the pipeline to development and clinical application has fallen to an unacceptably low level. More recently, the European technology platform – ETP Nanomedicine has identified open innovation as essential for bringing novel nanomedical devices from the laboratory to the patient, driving it towards a requirement for NMP FP7 Nanomedicine calls for proposals.

In practice, the world has moved on from the basic concept in Figure.2. The successful and rapid creation of meaningful solutions that really contribute to meeting the needs of citizens can only be achieved when all stakeholders contribute to the 'co-creation' of useful products. The starting point of the co-creation process is to gain deep insights into people's needs and aspirations by following a process requiring end-user input at every stage. For example, for healthcare products this requires intensive interaction with both patients and care providers. Subsequently, the insights are transformed into innovations by combining the diverse perspectives of different disciplines, and by actively engaging the users in product development. Thus the implementation of the solution is accelerated by considering the mode of implementation (e.g. workflow, business model innovation) and by involving all stakeholders: users, payers, regulators etc. Co-creation is an approach to innovation in which partners are brought closely together in a spirit of Open Innovation, not only conducting joint research, but also joint development, joint evaluation, and joint validation of novel products and solutions.

A number of different open innovation models have emerged within Europe that are showing promise as best practice for the industrial sectors served by NMP:

- Large industry model
- Regional Industry-led "Open Innovation" Centre Model
- Regional University-Industry "Open Innovation" Centre Model

All 3 offer distinct advantages for both large industrial companies and SMES. The first naturally favours large innovative companies. The two regional models are particularly effective in providing a range of support measures for emergent technology SMEs. New measures are needed within the common strategic framework (CSF) for 2013-2020 to consolidate what has been achieved and roll out best practice across Europe and industry sectors.

5.1 Large industry model

Leading European based multinational companies have developed excellent examples for their sectors: *(e.g. Intel, Bayer, BASF, Evonik-Degussa, Philips, GE, GSK, UCB, Roche etc….).* Many of these companies have published some details of their respective open innovation ecosystems. Models applied by large, multinational, companies are strongly dependent on the particular industry in which they operate. For example, Philips, a company active in the area of health and wellbeing, it is essential to develop products and solutions that address real and unmet needs of the users, patients, care providers, consumers. For applications in Healthcare, regulatory and reimbursement demands must also be met. Creation of innovative solutions in health and wellbeing requires collaboration of partners contributing expertise from different disciplines, bringing together academic and industrial partners, but also all the other stakeholders involved. To create a product in general the contributions of a number of companies are brought together: companies coming from different disciplines, component and intermediate product manufacturers, acting as suppliers, system integrators, and providers of the final solution, which may be a product, but also a service built around a product. Solutions need to fit in the workflow, or in the way of working in the application area concerned. This approach used for the development of innovative solutions is called 'Co-Creation'.

5.2 Regional Industry-led "Open Innovation" Centre Model

Typically these are based (but not exclusively) near a major industrial company and supported by regional or national development funds. They provide open access to high technology pilot plant scale facilities. They have strategic partnerships with major industrial players and create or support SMEs and are themselves operating businesses.

A detailed case study of best practice is:

a. **High Tech Campus (HTC) Eindhoven** (Hotspot for People Focused Innovation co-located with Philips innovation engine).Ten years after its establishment, High Tech Campus Eindhoven is today an R&D ecosystem of more than 90 companies, in a dynamic mix of multinational companies, small and medium-sized businesses and technology start-up companies, and institutes, comprising more than 8,000 researchers, developers and entrepreneurs, who together are working on developing the technologies and products of tomorrow. Philips has invested over 500 M Euro in establishing the HTC, Philips Research added about 100 M Euro to build its unique R&D infrastructure and facilities. The preferred way of working at the Campus is open innovation. This means that Campus companies share knowledge, skills and R&D facilities (such as labs, clean rooms and equipment) in order to achieve faster, better and more customer-oriented innovation. Examples of such cooperation are exemplified by the open innovation programs of Holst Centre, Centre for Translational Molecular Medicine, and the shared laboratory and analytical facilities at MiPlaza.

Expertise on the Campus spans a range of disciplines comprising High Tech Systems, Microsystems, Embedded Systems, and Life Sciences. Taking these domains as their starting point, the residents of HTC create global innovations, most notably in the application field of life technologies, creating solutions in Healthcare. The nearby site of Philips Healthcare in Best accelerates the product creation process. The Campus is a place where creativity, entrepreneurial spirit and high-end research can flourish and lead to successful global business. Innovation services, offering access to entrepreneurs, HRM facilities for flexible talent, legal and IP support, venture capital, experts on quality and regulatory affairs, and of course access to venture capital, create an optimal ecosystem for SME's and start-up's to grow into successful companies. Located at the heart of Europe's leading R&D region, High Tech Campus Eindhoven is the *Hotspot for People Focused Innovation*.

In the recently published study executed by Buck Consultants for the Dutch Ministry of Economic Affairs the High Tech Campus has been singled out as a mature Campus of national interest. The European Institute of Technology has chosen to establish the Knowledge and Innovation Centres ICT Labs and InnoEnergy, integrated partnerships, bringing together excellent higher education, research and business, at the HTC

Other outstanding examples are:

b. **Chem2biz** (www chem2biz.de) based at BASF site, Ludwigshafen, DE. Specialises in nanotechnology, new materials and bioprocessing.

c. **Chemelot** (www.chemelot.nl) based at DSM's site, Limburg, NL. This is a large site with 18 R&D companies, 15 running businesses, 10 start-ups and 76 service providers.

d. **MINATEC** (http://www.minatec.com/en/minatec) has been created by LETI (CEA's *Laboratoire d'Électronique et de Technologies de l'Information*) and INPG (*Institut National Polytechnique de Grenoble*), and is a large "open innovation campus" specialising in micro and nanotechnologies, green energy and Nanobiotechnologies for healthcare and industry. Its partners are global. It has alliances with 12 leading EU universities, 6000 researchers, 5000 industrial jobs, 5000 students and creates ~5 spinouts per year.

e. **Centre for Process Innovation** (www.uk-cpi.com) based at former ICI site, UK specialising in bio-processing, printable electronics and carbon capture. It has some 6 industrial companies and 10 SMEs.

f. **F3 Factories for the Future** (www.f3factory. com) based at Bayer site in Leverkusen. It has 15 chemical and pharmaceutical companies, 5 research and technology organisations (RTOs) and 5 Universities.

With the exception of example d), the above cases are derived from the chemical and processing industries. Another class of regional large industry-facing open innovation centres can be identified with similar operational models to the above. These have been derived and led by world class research and technology organizations (RTOs. Good examples of these come from the electronics and ICT sectors, such as:

g. **IMEC**, the Nanoelectronics research centre in Leuven, Belgium (**www2.imec.be**). It was founded with a major investment from the Flanders regional government and partners with the Catholic University of Leuven. It has developed an open innovation model that has attracted partnerships with global industry leaders e.g. Intel, IBM, ST Microelectronics and creates and supports SMEs. It is now a European and global centre of excellence in nanoelectronics research and fabrication.

h. **LETI** (CEA's *Laboratoire d'Électronique et de Technologies de l'Information)*, Grenoble France (**www.leti.fr**). It core research platforms are in nanoelectronics, nanocharacterisation and imaging but it has diversified into design, nanobiotechnology and clinical technologies.

There are many other good examples across Europe[iv]. They are European centres of competence of strategic importance to NMP and operate globally. They are good examples of measureable best practice.

A key question to address is: Where are the strategic gaps that EU, national, regional and industry funding could lead to the creation of new EU open innovation centres of excellence in other sectors and increase their geographical spread?

5.3 Regional University-Industry "Open Innovation" Centre Model

These are Centres for Industrial Collaboration (CICs) and are based on the campuses of academic centres of excellence, in research areas related to the industry sectors served by NMP. They are either single centres of clusters of centres and are founded by regional or national development funds and strategic investments by the universities. They are professionally managed to become self-sustaining business, many of which are or become spin-out SMEs themselves working for and with the campuses of their parent universities,

They serve large companies and SMEs on a fee for access basis but are particularly attractive and for SMEs for access to latest technology but also for networking with SMEs and large industry partners within their respective open innovation models. They also facilitate new spinouts from universities and provide access to leading academics' knowledge in a painless for both entrepreneurs and academics.

Typically they offer:

- Contract R&D using latest science and facilities
- Consultancy with top level academics
- Contract C&M and standardisation for new materials and devices
- Venture Capital support

- IP Development
- EHS support
- Networks for sharing best practice & new business partnerships

An initial survey indicates there may be quite a number of these. Examples are given below in Table 1.

Table 1

Examples of Regional University-Industry "Open Innovation" Centres

Country	Universities
UK	6 Yorkshire Universities (13 CICs)
Poland	Silesian U of Technology
Germany	2 Hamburg Universities
Italy	4 Veneto Universities
Spain	UA Barcelona + 3 Institutes
Estonia	2 Tallin Universities
Finland	Tampere University
Israel	Various (Driven by SMEs)

Further research is needed to identify the range of such CICs. Some clustering may make sense, against the 3 pillars of N, M & P and KETS. An example of such a cluster might be "Nanofoundries". Whilst they deliver support to regional SMEs, their industrial partners are global and their SMEs operate globally. Like their regional Industry-led "open innovation" centre cousins they too are capable of being European centres of competence and operating globally

<u>Key questions to consider for Model-3 are</u>:

a. Strategic gaps where EU, national and regional funding could support the creation of new EU centres of competence?

b. How to increase their geographical spread?

c. Creating networks to spread best practice across Europe?

The issue of European regional funding is important as it might be a critical component for creating new centres of competence for both models b) and c). The start-up costs for model c) are much lower than for b) and are particularly suitable for increasing the geographical diversity of model c) across Europe. The ERDF was not designed for this purpose and is not suitable in its present form to support either model.

6. Accelerated Radical Innovation (Practitioner Tools)

Recently, Dismukes et al[v] have introduced a set of practitioner tools for reducing the time to market for emergent technology. These authors describe this process and tools as *Accelerated Radical Innovation* (ARI). It is based on the principles of Open Innovation, both theory and practice, described in Section 5 above. It is especially suitable for periods of rapid change in scientific knowledge and the emergence of new breakthrough technologies. Its practices are built on the experience of previous periods of rapid technology change such as the emergence and development of the internet, cellular communication revolution and the use of gene amplification[vi] in shortening the human genome project from 200 to 20 years.

By harnessing the agentic competences of the inventor, the entrepreneur and the manager, it seeks to create a 10x force principle for a given technology opportunity (i.e.. reduce time to market and cost of development by a factor of 10-fold relative to conventional industrial project management processes, without decreasing probability of success or increasing market risk of products introduced.

It employs a 10-step innovation process broken down into *Inception* and *Implementation* processes that are well-suited to technological and industry sectors served by NMP where targeted investment in nanotechnology, advanced materials and production technologies for factories of the future by Europe and its global trading block competitors has led to unprecedented opportunities for convergent technology products and processes.

<u>Open innovation</u> increases the probability of finding better key technologies and stimulating creativity for innovative products and services earlier. <u>Accelerated radical innovation</u> moves them to commercial and societal application faster and at lower cost and risk

With further development, the approach could be adapted to include the fourth key agentic actor, i.e. the capitalist or financial agent, and innovative new business and supply chain models. Within such developments new cognitive science developed for high-technology Factories of the Future[vii],[viii] could be included to strengthen the importance of the "manager" role at the agentic level.

In summary, ARI approaches are attractive for accelerating the development and exploitation of all 5 key enabling technologies (KETs) identified in the Europe 2020 vision. It is also suitable for delivering convergent technologies, e.g. *nano-, bio-, info-* technologies together with new *cogni*-science (NBIC). Further work to develop the *manager* and *investor* agentic roles within the ARI practices could increase its usefulness to NMP stakeholders.

7. A Strategic Gap? Management Research and Training

Management of Innovative Emergent technology Manufacturing Businesses
"…."Manufacturing management research and training has declined in Europe's business schools in the last 10 years. Professors tend to be > 50 years old and many will soon be retiring"…..

…….British Academy of Management survey (2009)

The observation above, by the British Academy of Management[ix] suggests a fundamental weakness in Europe's ability to deliver the promise of its investment in manufacturing research and innovation as represented by the current €3.5 billion FP7 NMP programme, the forthcoming EU 2020 Innovation Union flagship initiative and its KETs. The origins of the problem may lie in the growth and complexity of banking and financial services within the economies of many of the developed countries. This in turn stimulated social science, economic research and MBA training for the new international finance, banking and service industries amongst Europe's business schools, and the concomitant decline in importance of management science for manufacturing industry.

Urgent action is now required to address this imbalance. A current Marie Curie Initial Training Network (www.manetei.eu), illustrated below in Figure 3, may be a relevant source of ideas and a demonstrator project, for how this important challenge could be addressed. It specifically addresses the entrepreneurship and management of manufacturing businesses built on emergent *nano-, bio-, info-* technologies together with new *cogni*-science (NBIC).

Figure 3

Marie Curie ITN ManETEI

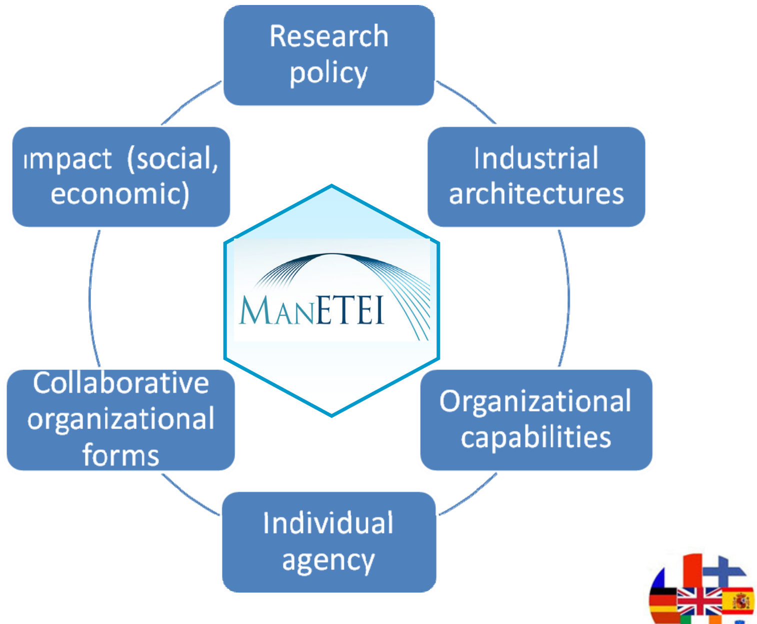
(Management of Emergent Technology for Economic Impact).

7 Business Schools
Leeds
Dublin (UCD)
Grenoble
Madrid
Rotterdam
Helsinki
Ljubljana

Technology Institute
Fraunhofer, ISI

Industry
Bayer (BTS)

Associate Partners
Intel
ST Microelectronics
Gorenje
OAS (Nanotech SME)
Lux (Consultancy)
PWC (Consultancy)
IP Group (VC)
Yorkshire (UK RDA)



Best practice in innovation at the agentic, company & EU/MS policy levels

Currently, it is entering second year of a 4 year programme, this initial training network addresses the management challenges and entrepreneurship at the agentic, company and EU/member states policy levels. It deploys a wide range of social, management and economic research and training methodologies including case studies, statistical methods and quantitative modelling of social and economic impact. It may help inform follow up work of this orientation paper and could provide an evidence base for informing future investment in world class MBA and business management doctoral programmes in emergent technology manufacturing and innovation, networked across Europe.

8. A Strategic Opportunity – Importance of ERC Research to NMP Innovation

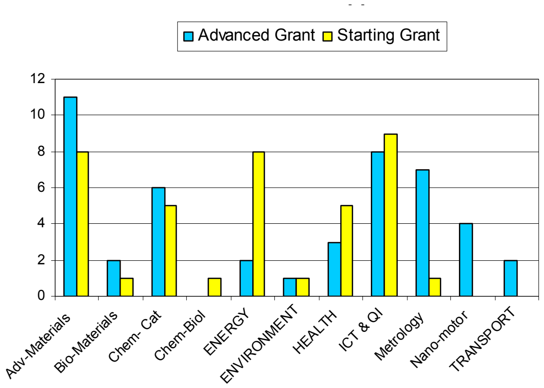
A grounded theory analysis[x] of <u>all</u> FP7 European Research Council (ERC) grants, at *Starting* and *Advanced Investigator* levels in the research domains of closest interest to NMP was undertaken[xi]. The purpose was to test the hypothesis that this population of investigator-driven research programmes led by the Europe's elite researchers might provide evidence based and better longer term indicators of technology trends of importance to NMP than traditional forecasting methods.

Figure 5a) revealed a number of important clusters. It confirmed the 5 KETs selected for the EU 2020 Innovation Union Flagship initiative and the importance of the EAG's orientation paper covering the KETs. It revealed some subgroups such as catalysis that may need more attention in NMP policy development. It also confirms the importance of metrology (and by inference, standards) and the need for the EAG's orientation paper on this topic. The importance of Europe's need for breakthroughs in energy, environment, its digital economy, transport and health is also reinforced.

An interesting additional observation emerged when 8 of 45 ERC Advanced Investigator Grant holders, selected at random from the 8 largest clusters, presented their research to the NMP EAG in Brussels on 4 November 2010. Half of them had led cooperative projects in framework programmes, had strategic partnerships with large industry and were involved with spinout companies based on their research.

Figure 4 Analyses of all FP7 ERC Advanced & Starting Grants (2007-2010)

a) Technology Cluster Analysis



b) % Nanotechnology Grants

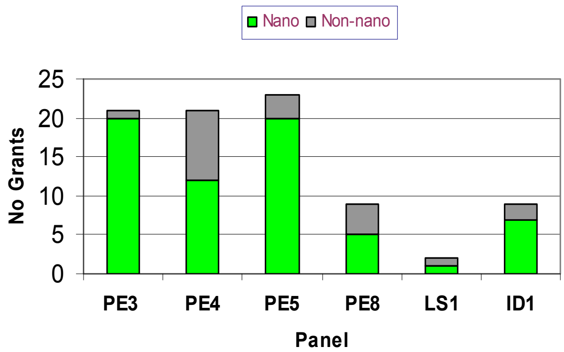


Figure 5b) is significant for a number of reasons. This analysis examines all the relevant physical science (PE) and key life science (LS) and interdisciplinary (ID) panel. No *a priori* assumptions were made regarding nanotechnology being a cluster or a KET or in the cluster analysis in Figure 5a). However, with 75% of all grants involving nanotechnology to a greater or lesser extent, it is clearly a very significant enabling technology in its own right and is incorporated into a diverse range of emerging advanced materials and device technologies. Hence it should continue to receive strong support in the EU 2020 Innovation Union flagship initiative separately for basic nanomaterial innovation but also in conjunction for future advanced materials for the supply chains of a diverse range of industrial sectors.

Given the results in Figure 5b), and the >€100 million invested during FP6 & 7 in nanomaterials environment, health and safety (EH&S) research it is surprising that there have been no ERC awards in this very important area of research. Given the continuing public, political and industrial interests in ensuring EH&S safety of nanotechnology, there may be case for strategic funding of world class independent investigator driven research in this field for NMP and the Metrology and Standards community to consider?

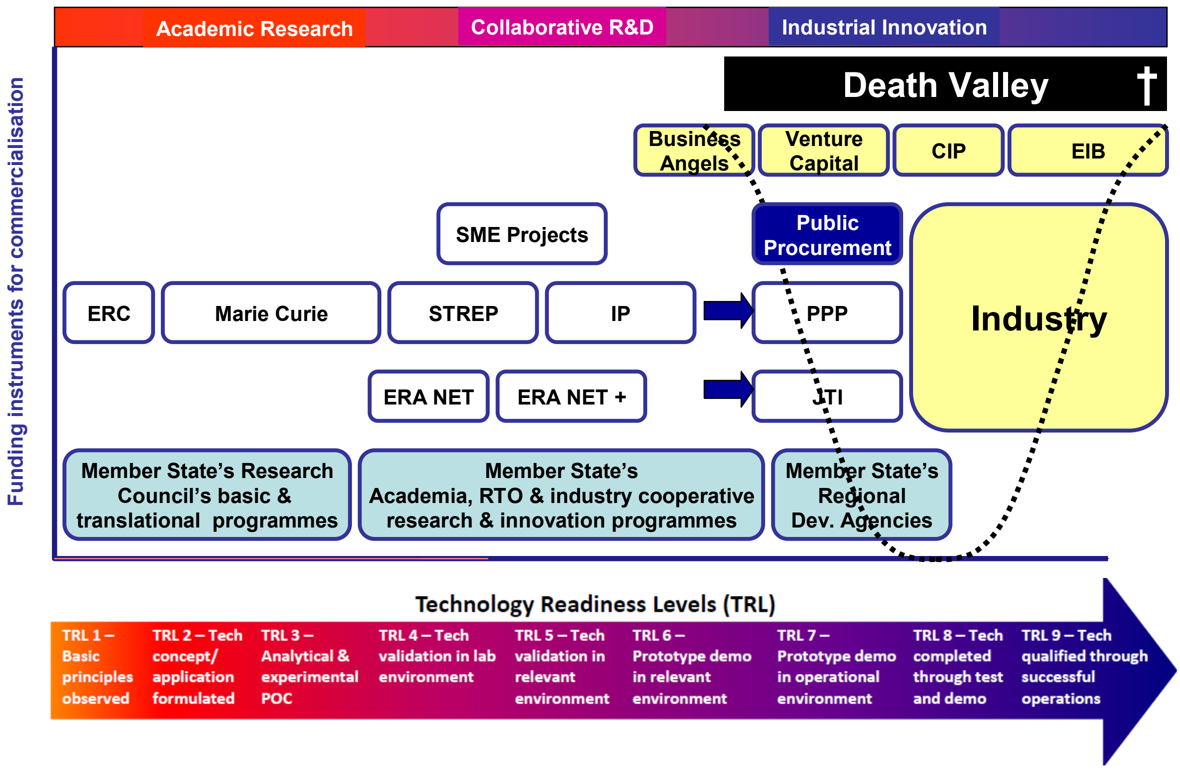
In summary, we recommend that NMP improves upon our feasibility study to data mine ERC projects regularly for early indications of future emergent technologies to be supported by NMP and identify specific science and technologies for rapid translation via accelerated radical innovation processes. Lastly, consider stimulation of ERC research in nanomaterials EH&S. In this way NMP best innovation practices can make an important contribution to Action Point-5 in the Innovation Union plan, concerning enhancing the role of the ERC.

9. Death Valley

The use of Technology readiness (TRLs) provides some clues to understanding and solving the *Death Valley* problem. Historically, EC and national public funding research has targeted academic research and pre-competitive R&D taking technology or service innovation from ideation and research up to precompetitive development TRLs 5&6 (see figure 5.

Figure 5

European Public Research Synergies (EU & MS)



Death Valley occurs, for both large companies and SMEs; if there are insufficient funds take move the technology into the zone TRL's 7-9. Existing funding instruments are adequate for TRLs 1-6. New instruments such as the public-private- partnerships (PPPs), a major feature in the upcoming *Innovation Partnerships* in the EU 2020 Flagship Initiatives (2013-2020) will need to move from their position to the left of death valley to straddle both pre-competitive R&D (TRLs 4-5) and competitive industrial innovation. (TRLs 7-9) as indicated by the arrow in Figure 5.

In making adjustments to PPPs in order to make this move innovation downstream to market, a number of critical issues will need to be tackled:

9.1 Funding the competitive component: Different solutions will be needed for incentivising large industries and SMEs

9.2 Public procurement: In some specific sectors, where large *first in class* fabrication plants need to be designed and engineered for manufacturing complex devices on very large manufacturing scales *(e.g. next generation nanoelectronics ICT or energy devices)* the introduction of new public procurement processes are needed overcome death valley in these sectors and ensure Europe remains competitive and jobs are remain in the Union[xii].

NB: The critical issue is ensuring a level playing field for Europe in the competition with SE Asians states and elsewhere..

This subject is discussed more fully in the EAG's *Key Enabling Technologies* orientation paper

9.3 Intellectual Property: Additional protection will be needed for the competitive component. Acceleration of a simpler, faster, cheaper and more competitive patent system is strongly urged

10. Other Areas Affecting Innovation Best Practice

The following four areas have been addressed in 4 specific EAG Orientation papers:

a. Standards & metrology

b. Environment, Health & Safety risks and costs for nanotechnology

c. Simplification & SMEs Related Issues (EU patent system)

d. Interactions Academia &Industry

They need to be addressed to remove potential innovation road blocks and widen of best practice in innovation across Europe.

Standards and Metrology: Specific measures needed are as follows:

- Europe has world class national metrology institutes (NMIs). But the Article 185 European Metrology Research Programme (EMRP) ends in FP7. A new pubic: public investment programme for EU metrology and standards research is needed for the next framework (CSF)
- Europe has world class standard bodies (CEN/CENELEC). Measures are needed in the CSF to accelerate EU standards generation.
- China is a rising force in standards and metrology. A European strategic plan is needed in the CSF to deal with opportunities and challenges of this development.

Nanotechnology Environment, Health & Safety: Europe EU/MS invests ~€ 2 billion/year (33%/67%) per year in nanotechnology research and innovation. NMP has created an innovative €102 million portfolio of world class research in the new sciences of nano Environment, Health & Safety (EHS). This is a demanding new and complex area of research still in its infancy. With the size of the annual investment in nanotechnology by industry, the EU, Member States' governments, regulatory bodies and citizens, there is considerable pressure on this new research community to provide guidance to all stakeholders to enable the Union's nanotechnology innovation processes to power ahead, knowing that products and devices are safe through to end of life. Specific measures are needed to:

- Maintain the nano EHS research momentum achieved by the current NMP Directorate in the next framework
- Bring forward necessary infrastructure investments in the next framework to build public and industry confidence together with regulation to keep out unsafe imported products
- Accelerate socio-technical integration research with public engagement for responsible nanotechnology management

11. Funding Instruments and EU & Member States Synergy

Industry urges caution regarding the introduction of new funding instruments. Any new instruments will need justifying by a business or economic case. Removal of redundant instruments is recommended where possible.

No new instruments are foreseen for TRLs 4-6. However, modifications to PPP's should be explored to gain momentum in to TRLs 7-9. For large companies, these may range from R&D tax credits or EIB support to consortia. For SMEs these may credit lines, grants or other instruments. The role of ETPs will be important as they will change from being 'advisory' to 'executing' in the development of the PPPs and their migration to straddle Death Valley in the upcoming common strategic framework and thus will have a critical role developing emergent technology areas?

Regarding other Instruments, STREPs and IPs remain relevant and could be used to tackle technology roadblocks within PPPs or accelerate progress with emergent technology. Networks of excellence such as the ERA-Net and ERA-Net+ have proved their worth in FP4-FP7. In particular, in the area of NMP's responsibility for standards and metrology, these instruments were used across frameworks to develop the ambitious €600M European Metrology Joint Research Programme, funded by an Article-185 public ; public partnership between the EU and member states.

EU & MS synergy needs more work. They increase funding availability but increase complexity, exclude less favoured MS and delay innovation.

12. Engagement with Venture Capital

Recent research[xiii] has shown that the larger Venture capital organisations tend to be located in a few EU Financial centres such as London, Frankfurt and Paris and that their connections to investment opportunities in the regions are weak. In consequence, innovators and entrepreneurs whose research or businesses residing in the regions have to work disproportionately harder than their counterparts located near the few cities where the bulk of the venture capital groups are located. There are a few examples of best practice of best practice in amongst all three open innovation models (GSK, Chemelot and IP Group respectively), where some venture have taken up regional residence. Learning from these leaders could help SMEs solve their Death Valley problems.

13. Recommendations

The very nature of the best practice in innovation discovered within Europe during the preparation of this orientation paper suggests a total system approach is needed. Thus, co-creation of new products and services via open innovation by large companies and SMEs, must be tackled alongside and addressing the Death Valley problem.

13.1 Large company model Open Innovation model

Move key instruments PPPs, JTI, Innovative Medicines Initiative to straddle Technology Readiness Levels TRLs 4-5 & TRLs 7-9.

13.2 Regional Industry-Led Open Innovation Centre Model

Create PPPP models (inc EIB) to fund flagship centres with critical mass for game-changing technologies. Specific support is recommended to:

a) Identify regions and technologies where new opportunities exist

b) Set up public procurement PPPP process to roll out new centres across Europe

13.3 Regional University-Industry Open Innovation Centre Model

Stimulate the creation of European Centres for Industrial Collaboration (ECICs) at academic centres across Europe with proven track records in NMP science and technologies. The following process is recommended:

Phase-1: Demonstrator project, business plan and foundation network.

Phase-2: Roll out of concept to regions across Europe to complete the network.

NB: The funding model should be designed to create a self-financing and sustainable network or clusters of networks

13.4 Death Valley for SMEs

For fast moving innovative SMEs creating new businesses and markets, a European Innovation Council (EIC) should be created on a similar basis to the ERC. Whereas, the latter supports excellence in *investigator-driven* projects, the EIC would support excellence in *innovator-driven* projects. In much the same way as the ERC, an annual bottom-up "best of the best" competition should be established.

NB: Detailed work on sources of funds, mentoring of entrepreneurs and mechanism for return on investment from successful SMEs to the EIC will be required.

13.5 ERDF is "not fit for purpose" for Open Innovation Model-3 (ECICs)

Create a European Regional Innovation Fund (ERIF) for supporting the development of the European Centres of Industrial Collaboration.

NB: The fund could also support the Regional Industry-led Open innovation centre model but needs to be more business impact focused with much lower administrative burdens than the ERDF

13.6 Engagement with Venture Capital

A special study is recommended to explore ways of making more effective connections between the larger venture capital groupings located in the EU's leading financial centres with those associated with best practice in Open innovation models -1, -2 and -3.

13.7 Capacity Building in Elite Business Schools

A number of measures are recommended to reverse the decline in research and training in Europe's business schools for future entrepreneurs and executives emergent technology businesses:

a. Increase funding for further research and PhD training (SSH)

b. Stimulate professional doctoral training centres across Europe in emergent technologies at elite European business schools for highest quality innovation management research and practice training.

c. Phase-1 funding to create foundation network of elite business school research & training

d. Phase-2 funding to roll our best practice across Europe.

NB: The above should be developed via a 2-phase programme with support from the European Institute of Technology (EIT) to bring the EU's elite business schools up to the level of the world's No 1 centre (www.wharton.upenn.edu).

13.8 Measurement, Modelling and Forecasting impact

A review of best of practice and current research in determining both the economic and societal impact, including spill-overs, of research and innovation programmes should be conducted. It should lead the development of new tools for measuring the effectiveness of NMP (ET) research and innovation processes at the programme and macroeconomic levels

13.9 Technology Forecasting

A process should be developed within the Commission's Research and Innovation Directorates to build on the EAG's ERC pilot cluster analysis study to undertake periodic reviews of future 'hot areas' of technologies and likely trends that could enter the research an innovation in the next framework

13.10 EIT Knowledge & Innovation Communities (KICs)

At the time of writing there is a proposal for a future KIC to be established in Advanced Manufacturing The EAG is willing to work with the EIT to assess the feasibility of establishing NMP KICs possibly in conjunction with the its proposed open Innovation models -2 &-3 and relevant PPPs.

References

[i] Kiparissides C (Ed.) NMP Expert Advisory Group (EAG Position Paper on *Future RTD Activities of NMP for the Period 2010-2015*, EUE 2241179, European Commission, (2010), Brussels

[ii] Schumpeter, J.A. *The theory of economic development : an inquiry into profits, capital, credit, interest, and the business cycle* translated from the German by Redvers Opie (1961) New York: OUP

[iii] Chesbrough, H.W., Vanhaverbeke, W. & West, J., (2006), Oxford University Press.

[iv] "Germany: Europe's Prime Location for Innovation & Production", Invest in Germany, ICIS Chemical Business (Supplement), March 2008, ICIS, Surrey UK

[v] Dismukes, J.P., Bers, J.A., Miller, L.K., Dubrovensky, A., "Technological Forecasting & Social Change", 76 (2009) 165–177

[vi] Markham, A F, A yeast artificial chromosome "contig" encompassing the cystic fibrosis locus, Genomics, Volume 9, Issue 1, January 1991, Pages 124-130

[vii] McGourlay, J., Ridgway, K., Davis, M., Challenger, R. and Clegg, C. (2009). Designing the Factory of the Future. Paper presented at Design for Human Performance, a one day conference organised by Arup, 26th February 2009, London.

[viii] Clegg, C. W., Ridgway, K., Hollis, K., Curd, N., & Lynam, E. (2007). Helping Design the Factory of the Future. Paper presented at the 13th European Congress of Work and Organizational Psychology, Stockholm.

[ix] Thorpe, R, (personal communication to Rapporteur) "Trends in Manufacturing Management Research and Training", British Academy of Management, (2009), London.

[x] Thomas, G. & James, D. (2006). Re-inventing grounded theory: some questions about theory, ground and discovery. *British Educational Research Journal*, 32 (6), 767–795

[xi] Wilkins, T.A. and Deliyanakis, N., Unpublished study, presented at the NMP EAG meeting, Brussels 4 Nov., 2010,

[xii] Neugebauer J-G, Baldi, L., Mudry F., Hossain, K., and Goericke, D., " Key Enabling Technologies", NMP EAG Orientation Paper, 2011

[xiii] Westwood P., "Study of UK Venture Capital Practice for SMEs in Emergent Technology ", ManETEI MC ITN Summer School, Leeds, June 2011

III. Simplification and SME Involvement

Carine Moitier, with the NMP Expert Advisory Group

Foreword

This paper refers to the following documents:

- European Experts Panel on SMEs – Measures to foster SMEs' participation in R&D&I activities and synergies promotion in support of innovation and SMEs – still under redaction
- Commission Decision of 24th January 2011
- Un pas vers une plus grande sécurité juridique et financière des projets du 7eme programme-cadre ANRT-Europe December 2010
- Interim Evaluation of the Seventh Framework Programme – Report of the Expert Group - Final Report 12 November 2010
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – 29 April 2010

Further to those readings, this paper is nourished from personal experience as a micro SME entrepreneur having contracted with both regional as well as European research projects. This evaluation report focuses only on recommendation aspects of the EU grants, not on the global picture including other aspects like regional or national programmes, venture capital,…

Introduction

While it is important to retain stability in much of the FP and to avoid disruptive changes to procedures with which the research community has become familiar, there can sometimes be reasons to change tack. The severe financial and economic crisis has given us a new world full of opportunities to tackle with in an open Internet environment helping our everyday life. The world is changing faster and faster, there is a need to be **more agile, flexible, entrepreneurial, quick to create added value for the final European consumer.**

Today competition is moving from products to eco-systems1 and European research projects help companies, in particular SMEs contribute and be part of such eco-systems.

Research, Innovation and Science Commissioner Maire Geoghegan-Quinn said: "Our proposals aim to minimise administrative burdens in Europe's research programmes. We need to get the best researchers and most innovative companies taking part and we need to enable them to concentrate on results, not red tape. That will boost Europe's economy and quality of life. In particular, **we must encourage more SMEs to join in**. I believe this can be done without compromising financial control. We are asking the other EU institutions for support to achieve this."

The Definition of a European micro SME as it is today

"Small is beautiful", small is agile, flexible and reactive but also financially fragile. In Europe most of them are family business "vivons heureux, vivons cachés". They do not want to share with others nor their know-how nor their figures. They have an independent spirit working in a "commando" way having light and concrete meetings. They are talented people more focusing on doing. They are working nights and days to make a successful business or stay alive in this extremely competitive open market. Often, they do not take enough time to get a strategic helicopter view. Entrepreneurs in micro SMEs are "all-round" people dealing with any kind of task from making new customers, recruiting people, cleaning the room, accounting figures, …they are also their own advertisers as they do not have big Marketing budgets to spend.

They are very pragmatic people. More and more know that innovation is key in a world where you need to bring real added value for the final European citizen. But the way to innovation is quite a long journey: innovation becomes riskier, more costly and is needed already for yesterday. If they fail, there is a huge risk to die and eventually start again. Cash drain is the main concern at the end of each month. Entrepreneurs pay themselves very lightly, nothing to do with big companies CEO salaries which can reach 500X the salary of a company receptionist. (30 years ago it was X 20). A survey carried out by the European Commission and the European Central Bank shows that the crisis has hit European SMEs with 51% indicating that their profitability has decreased over the last six months. On average, 16% of the SMEs (up from 11% in the first half of 2009) reported an increase in their need for bank loans. By contrast, the average of large firms reporting an increase in the need for bank loans remained lower and broadly unchanged. **Most SMEs can go bankrupt at any moment.**

Mr Elop highlighted the need for Nokia to have a competitive smartphone "ecosystem" that combines user-friendly hardware, software and services. He added Nokia must "build, catalyse and/or join a competitive ecosystem" S.Elop, Nokia CEO, FT 27/1/11 @ http://www.ft.com/cms/s/0/255a8506-2a07-11e0-997c-00144feab49a.html#axzz1Dr28PYvf

The Definition of SME adopted by the European Commission

SMEs comprise 99% of all companies in Europe and a high share of total employment estimated at around 65 mio. They are the primary source of net job creation in Europe. They are performers of research, especially in some of the leading-edge 'new' economy sectors, as well as consumers of knowledge.

The European Commission's definition for SMEs is the following: SMEs employ fewer than 250 persons and have an annual turnover not exceeding 50 Mio €, and/or an annual balance sheet total not exceeding 43 Mio €. Additional conditions for autonomy apply.

The concept of SME includes micro, small and medium enterprises; nevertheless it is clear that the positioning, priorities and even financing capacity of a 200 people company is different from a 10 employee company. This classification could therefore be rethought in order to serve the different needs of the SMEs under this classification, namely the R&D needs.

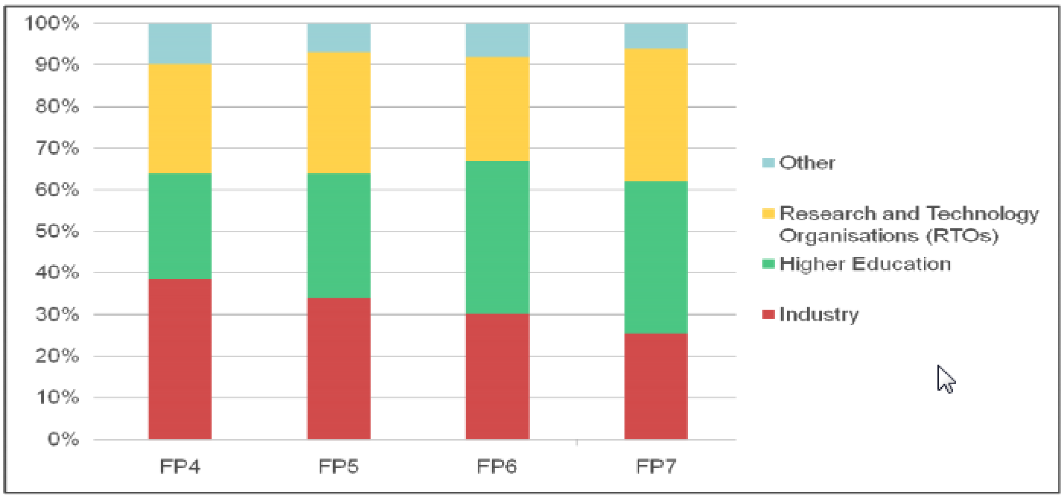
The typical European firm is a micro firm. This is especially important taking into consideration the weight that SMEs have in European economy, being a major job engine for Europeans. Within the non-financial business economy enterprise population, almost **92% are micro enterprises, having a staff headcount of less than 10 but being responsible for 29.7% of employment**. About 1% (226.000) of enterprises are medium-sized. Further more, we understand that 54.6% of the people employed in the R&D sector are working in SMEs.

This scenario shows a tremendous contradiction with respect to the participation of SMEs in the cooperative research programmes, as they participate below 15%.

Involvement of Industry and SMEs today

The Framework Programme has to cover the whole innovation process from basic research, applied research to market relevant demonstrators. Companies are the major drivers in bridging the gap between research results and innovation. Yet, despite the acknowledged importance of both large companies and SMEs in this role, **industry participation**, whether as a share of funding or number of participants, **has been declining continuously for 15 years**. As figure 7 shows, it fell from **39% in FP4 to 31% in FP6 and currently accounts for only 25% in FP7**. In essence, the cash is not the main reason for large companies to participate. Rather their motivations are primarily to gain access to trans-national R&D-networks, knowledge creation, idea generation, and strategic partnering for long term cooperation and pre-standardization.

Figure 7 Participation by stakeholders



Source: European Commission, Second FP7 Monitoring Report, October 2009.

Today it is recommended that SMEs represent 15% of the participating entities. This number is only a recommendation not a target and it is actually less than 15% according to the Mid Term Report on SMEs' participation in the 7th R&D Framework Programme. Nevertheless, SMEs are most prominent in the nanotechnologies and new materials, and the security sub-themes of Cooperation. Provisional data suggest that SMEs will exceed the 15% target for participation in JTIs.

The average success rate of SMEs applicants is 17%, compared to 20% for all applicants, pointing to a higher rate of wasted effort by SMEs which could be a deterrent to their engagement according to the Third FP7 Monitoring report.

Unfortunately there is no **data available about the innovation power of SMEs that have taken part in FP7**, nor the extent to which projects in FP7 have resulted in the creation of new high-tech firms. Nevertheless, figures from FP5 showed that SMEs innovate 4 to 6 times more for each € grant received. FP6 datas will soon be available.

Recommendations to boost SME participation

To increase the participation of industry and SMEs the Commission must reduce the administrative burden significantly and the arbitrariness of auditing practices. The Commission should create a flexible, lightweight and well-defined form of sub-contracting or associate partnership for SMEs. **More effort should be devoted to achieving greater impact regarding innovation,** in stimulating the participation of industry and SMEs, and in focusing on the whole innovation process. Without addressing these challenges rapidly, future Framework Programmes are unlikely to fulfil expectations of their contribution to innovation in Europe. Moreover**, the Commission has to switch from a low-risk, low-trust attitude to a more trust-based and risk-tolerant approach conform the everyday life of an SME today. This is the approach taken by the widely praised SBIR programme in the US.**

Smaller variety of funding rules

Over 25 years, the EU's Research Framework Programme has expanded significantly in terms of scope and budget. (In 2009, EU research funding represents 7.5% of the overall public funding in Europe). This results in more participants and a need for more controls to ensure that the EU funds are spent correctly. To achieve this, a number of different rules and administrative procedures were developed, but participation in EU-funded projects became complex. Multiplying checks under complex procedures is not the best way to achieve value. It is time now to restore trust and simplicity which will also conduct to **save time and money as well as be more effective.** As background information on the Commission side, the cost of implementing the Research Framework Programme was about 267mio € in 2008.

According to a submission to the Interim Evaluation Expert Group, there are 700 new rules in FP7, and even if there is some exaggeration in this figure, it is hard to square with a simplification agenda.

The following shopping list is a summary of what should be done:

No ex-ante financial capacity checks to ease participation of SMEs and high-tech start-ups. According to the Commission, today 80% of FP7 participants are already exempt.

Exemption of certificates on financial statements to be provided with periodic cost claims. According to the Commission, today 75% of FP7 participants are already exempt. This will save tens of millions of euros compared to FP6.

Maintenance of a single registration facility. Nearly 22.000 entities are already registered.

eFP7 should be intensified with improved IT tool and guidance as well as helpdesk especially focusing on newcomers. There are still too many problems with IT tools , and poorly harmonized application, the current use of different systems is confusing and complex. Access to the programmes and preparation of proposals are still too difficult, in particular for SMEs.

Time to grant (TTG) for micro SMEs should follow the same model as ERC's "time to grant" of less than 20 days on average comparable with major funding institutions such as National Science Foundation (NSF) and the National Institutes of Health (NIH) in the United States. For other SMEs types, that time should be of 47 days maximum as the actual FP7 minimum see Table 2 hereunder.

Table 2 Time to grant in days for FP7 grant agreements signed in 2007-2009 by thematic area (as of May 2010).

SPECIFIC PROGRAMME	THEMATIC AREA	GRANTS	MINIMUM	MEDIAN	MEAN	MAXIMUM	STD
COOPERATION	Health	379	96	417	439	804	126
	Food, Agriculture and Fisheries, and Biotechnology	144	282	450	448	650	85
	Information and Communication Technologies	820	178	248	252	466	41
	Nanosciences, Nanotechnologies, Materials and new Production Technologies	244	190	401	394	609	77
	Energy	149	63	338	337	544	103
	Environment (including Climate Change)	181	47	530	493	651	105
	Transport (including Aeronautics)	261	223	541	525	926	104
	Socio-economic sciences and Humanities	110	223	429	432	782	115
	Space	25	94	533	478	724	150
	Security	60	228	556	530	929	194
	General Activities	19	112	374	324	493	138
IDEAS	ERC	835	160	318	314	602	69
PEOPLE	Marie-Curie Actions	2.634	122	322	324	650	96
CAPACITIES	Research Infrastructures	150	127	365	372	641	119
	Research for the benefit of SMEs	248	177	443	456	749	101
	Regions of Knowledge	42	234	306	333	589	97
	Research Potential	102	239	358	353	469	53
	Science in Society	79	56	386	370	573	124
	Support for the coherent development of research policies	12	53	225	256	538	128
	Activities of International Cooperation	44	227	310	324	717	100
Total		6.578	47	335	350	929	118

Source: European Commission, Third FP7 Monitoring Report (Monitoring Report 2009)

In most cases, at national and regional research programmes level, the financing is given long after the project has started which is worse than the EU FP7. You would have expect the opposite situation here. This is one of the biggest obstacle for SMEs to join the European Research.

Furthermore, at EU level, pre-financing payment is made at the start of the project corresponding to 80% (in FP7 for example). Therefore, the implementation of similar rules should be applied to national and regional research programmes in order to stimulate SMEs participation. Given the current economic situation, the recommendation would be to **offer a pre-financing payment of 100% as a mean to attract more SMEs to R&D.**

Schedule of calls and topics**: calls with larger topics or open calls with cut-off dates to shorten the time to the next funding application**; Structure and timing of calls for proposals optimization by taking major holidays periods into account. Intensify information prior to call and give longer periods to form consortia and prepare proposals: increase the time between call publication and deadline beyond the standard 3 months.

Use a 2-step proposal submission (pre-proposal – full proposal if successful), where only the best proposals would pass to the second stage, so that SMEs could be better advised and the preparation effort would only be dedicated to the best proposals. It would be necessary to avoid even a longer 2-step process that is why the first stage would just be a short SME-business needs test, not based on a fully drafted research project proposal. Proposals proceeding to the second stage ought to have a 30-50% chance of acceptance.

Avoid the need for beneficiaries to set up separate accounting systems. This provides more legal certainty for beneficiaries and diminishes the risks of errors. The obligation to open interest-bearing bank accounts and to recover interest on pre-financing would be removed.

Move from a cost-based funding to a result-based and IPR approach. This step should be considered in order to really reposition the focus on the results and impact much more than on the format or costs as it is the case today. A variable bonus grant could be imagined in order to stimulate excellence of results above excellence of project proposals as well as costs.

Ensure a single audit approach in the research area – A task force has been established by the Commission to review the coordination mechanisms between the Research DGs. Too high level of detail is required for audit certificates and the upshot is a “zero-trust” policy. There should be a coordinated audit management.

Avoid overly demanding reporting obligations, including what appears to be needless duplication of reporting. Consistency in the application of rules or implementation of procedures. The main conclusion of a recently completed study for the European Parliament by Deloitte Consulting is that the manner in which the rules are implemented is more problematic than the rules themselves.

“**Less management costs and more research**” within each granted research project. The focus on reporting and financial issues should move to exploitation of research results. Difficulties still arise in project management due to heavy reporting procedures and big size of consortia. SMEs should be able to take an effective head in developing research projects, also as coordinator if needed.

The possibility to **complement grants with loans** should be explored. SMEs may benefit from having access to the 100% of the overall cost of their investment in the R&D projects (for example: 75% may be direct grants and 25% loans on advantage conditions). The **level of grants for SMEs could also be revised** according to the sizing of the SMEs : Micro SMEs, up to 90% of eligible costs – Small SMEs, up to 80% of eligible costs – Medium SMEs, up to 75% of the eligible costs.

Smaller consortia

SMEs become close to dilution in very large Consortia. SMEs feel extremely isolated and marginalized when working in large project Consortium, usually forced to take part in this consortium if they want to be part of the research and innovation activities (usually, there would be just one project running per year in this kind of large programmes), where their role and possibility to influence is minimal and diluted. Consequently, a revision of the criteria “impact” and ambition goals of the research programme might immediately lead to more natural sizing of projects, where **3 to 5 entities can build a successful research story, not needing an artificially large consortium.**

Nevertheless, integrate the possibility of **allowing SMEs to enter a project in its latest stage or under subcontracting** especially for micro SMEs could really help them to jump in the research train. Indeed, it is fundamental to assure the involvement of SMEs, once it is the closer stage to the product commercialization. Many SMEs do comment on the attractiveness of the research programmes when they perceive innovation opportunities. Brokerage events could be organized for EU partners to market their best potential results.

Industry- and result-driven R&D programme

In order to get more industrial companies and especially more SMEs and in particular more micro SMEs on board of research for a better chance of innovation breakthrough, **the R&D programme should be much more industry oriented and driven than it is today.** Research entities should listen much more to SMEs needs and support them to get there than the other way round. This will also help not only SMEs to get to research but also large companies that are still under represented today. This concretely means that the number of coordinators being SMEs should become a reality and really increase. SMEs should be able to create a full proposal from scratch; from finding the right partners, writing a proposal, summit and defend their project with success and showing breakthrough results at the end of the project. Indeed, the result impact should be much more successful and closer to the market with a quick commercialization target.

More Industry and SMEs driven R&D programme will conduct to more result driven European Research.

Conclusions

As per Eurostat statistics, SMEs do perform research and innovation activities at a level of more than 50% of the SME universe in Europe. The fact that SMEs do participate only for 10 to 15% in publicly funded projects, suggests that such R&D programmes are miss-focused regarding the interests of SMEs.

The implementation of each of the recommendations indicated above will imply financial or legal amendments to the current rules and practices. **The European Commission should review some of the recommendations in a similar way as the recent updates of the Grant Agreement** (decision of the European Commission of January 24th, 2011) at the light of revising the FP7 rules, on very important issues for SMEs and particularly for the micro SMEs.

Let's evaluate the impact of results of the Framework Programme and move from the evaluation impact criteria of "pure excellence" towards "excellence and exploitability of results-benefits for the community".

IV. Metrology and Standards in Innovation

Kamal Hossain and Robert Aitken

Supported by Søren Bøwadt, Romain Bouttier and Nicholas Deliyanakis

Introduction

This paper reviews the important role of metrology and standards in innovation particularly in relation to the development and commercialisation of new products and processes based on advanced and emerging technologies. Research on specific and high priority topics in metrology is supported under FP7; however, the need for metrology and standards to support the rapid development of a technology and its application is not addressed in a strategic way thereby missing real opportunities for Europe to gain from its strong scientific and technical capabilities in knowledge generation. Furthermore, results of R&D projects, where the primary aim is to enable the development of new products and processes may have significant potential to contribute to the development of European and International standards of real value but often not realized. This is because there are some practical barriers, which can be overcome relatively easily by treating R&D and standardisation in an integrated way. An analysis of these barriers and suggestions for overcoming these are presented.

Metrology and Innovation

Metrology and measurement have a vital role in supporting and enabling innovation to improve European competitiveness, as well as helping Europe to meet major societal challenges of sustainable energy supply, environment, security and health. It is widely acknowledged that reliable measurement:

- Supports R&D to develop innovative new products and processes;
- Help improve efficiency of industrial production and processes;
- Supports transaction costs in the market and allows buyers and sellers to have confidence in products and services.

Indeed, innovations in measurement technologies often become the basis for new industrial capabilities. For example, very high accuracy measurement of time has led to many new products and services based on GPS technology.

Innovation requires the application of knowledge generated from basic research into new products, processes and services where businesses face the highest levels of risk.

Work needed to convert laboratory-based results into successful commercial products and services carries huge risks due to market uncertainties. A robust infrastructure is needed for proving the technology, in developing prototypes, ensuring quality and performance reliability, and meeting standards and regulations. For technology-based innovation, measurement and testing is a vital part of this infrastructure and helps to reduce important risks in the market. In fact, much of the same test and measurement infrastructure is also needed for making scientific advances in emerging fields, for example, nanotechnologies. Hence, an integrated and balanced approach to infrastructural work and scientific research is fundamental to ensuring wealth creation through innovation. Indeed, the central role of measurement in innovation has been highlighted in a US report (1) as follows:

"Advanced measurement capabilities are essential to innovation in every major economic area and every stage of the innovation process. Advanced tools and measurements are required to innovate – to design and incorporate new and better features into the kind of next generation products and processes necessary for the United States to compete effectively and stay ahead in the global market place"

For mature markets, a technological infrastructure is in place that helps the market to operate:

Products and services can be accurately described so that suppliers and customers are clear what is being provided in terms of characteristics and performance. This is achieved in part through measurement and documentary standards, and these are usually recognised across national borders, to open up global markets.

Manufacturers and service providers are able to ensure the continued quality of what they supply, again in part reliant upon measurement and documentary standards.

Risks, e.g. to health and safety, arising from products and services are understood, and where significant, are controlled through design and regulation. This leads to confidence in the market place.

This kind of technological infrastructure has yet to develop for innovative products and services based on new technologies. For nanotechnologies, for example, terminology and test methods are needed early in the development cycle to assist manufacturers and users to be able to communicate and specify component and product characteristics and performance, essential for building market confidence and success. Similarly new techniques for measurement and testing at the nanoscale have to be developed and validated for reliable characterisation of nanotechnology based products and services.

Policy Context for Standards and Metrology

Metrology and standardisation will play a vital role in supporting the Europe 2020 strategy for smart, sustainable and inclusive growth. Europe 2020 Flagship Initiative (2) underlines that a dynamic European standardisation system is needed to support innovation. The Industrial Policy Flagship (3) emphasises the key role of standardisation to enhance industrial innovation in Europe and stresses the need for European standardisation to be highly responsive in a rapidly changing world, for it to support European competitiveness in the global market and for it to meet the needs of both industry and public authorities. The Digital Agenda for Europe (4) highlights the importance of ICT standards in developing interoperability between systems. European standards also feature in the review of the ‘Small Business Act’ (5) for Europe.

In Innovation Union, standardisation is recognised, as a key tool for innovation. It is also accepted that there is a clear need to strengthen relationship between research and standardisation.

Report of the Competitiveness Council on Standardisation and Innovation concluded (2008) that “standardisation makes an essential contribution to innovation and competitiveness by facilitating access to markets, enabling interoperability between new and existing products, services and processes, enhancing protection of users, giving consumers confidence in innovations, and disseminating research results”

The Commission Communication on Standardisation & Innovation (6) made the following recommendations:

- Public research bodies and public sponsors of research programmes at European and national level to examine the potential interest in order to exploit research results;
- The European Commission to encourage the financial support of ‘ technology watch’ activities in order to identify areas where standardisation could be useful in the transfer of research and development results;
- Both standards and patents to be recognised as innovation dissemination tools;
- The European Commission to support the use of standards in matters relating to sustainable industrial policy, lead markets, public procurement, information and communications technology and better regulation policy;

A new EC communication on standards (7) has been published recently and it is likely to be followed by legislative proposal to implement a strategy to promote a stronger role. Mr Antonio Tajani, Vice President of the European Commission has stated “To be successful, Europe needs to react to the challenge of rapid innovation, sustainability, convergence of technologies, and fierce global competition. A dynamic European standardisation system is essential to spur quality and innovation and to strengthen Europe's role as a global economic player."

Governments around the world have recognised the importance of having a measurement infrastructure that is objective and unbiased and provide public funding to ensure that the infrastructure keeps up with the national demand. Such an infrastructure will not be provided by the private sector as the benefits are widespread and open to many organisations, thereby representing a market failure argument for public support. Such an infrastructure must also be consistent with those of other countries as globalisation continues to move at a rapid pace. Beyond the infrastructure, many measurement methods and tools for specific applications are also needed and require R&D support. These can benefit specific users or wider groups and sectors. Development of such measurement technologies and their standardisation in some instances may be critical for rapid and wide-ranging innovations based on new technology. Many of the basic characterisation and measurement tools needed for exploitation of nanotechnologies provide good examples in support of the arguments presented here. A related issue is that many European SMEs need access to reliable and effective expertise and facilities for characterisation and testing of nanotechnology-based products they are developing. It is beyond the capability of individual SMEs to establish complex and expensive facilities and expertise in –house, and therefore support provided through a simple and cost effective mechanism would be invaluable This might possibly be provided through co-operation with the Europe wide network of Laboratories of EURAMET members (www.euramet.org).

A recent development deserves special mention in this context. The European Commission and 22 Member States have joined together to support, under Article185 of the Treaty, a major programme of Measurement research worth 400Million Euros in FP7 involving National Metrology Institutes and other Research Organisations. This is known as the European Measurement Research Programme (EMRP) (www.emrponline.eu.) and is managed by EURAMET, the European Association of Metrology Institutes. Directorate 2 leads on EMRP within DG Research. EMRP aims to integrate the development of Metrology research in Europe and addresses infrastructural aspects such as Measurement Standards for the base and derived units. It also covers the development of underpinning metrology increasingly required to support new technology based solutions for meeting grand challenges of energy, environment, health and sustainability. This work naturally supports the development of key metrology tools and will have the potential to contribute to new European standards e.g. measurement and monitoring standards for Smart Grids. EURAMET have recently signed a MoU with CEN/CENELEC to facilitate the transfer of research results from EMRP into standards.

The European standards organisations, CEN and CENELEC have recognised the importance of the inter-relationship between standards and research and established a group, known as STAIR (**STA**ndards, **I**nnovation and **R**esearch). STAIR is working to develop an Integrated Approach for Standardisation Innovation and Research (8).

The European Commission, in urgent and important areas, uses mandates to the European Standardisation organisations for developing standards to meet economic and regulatory needs of the European Union. Such a mandate has recently been made to CEN, CENELEC and ETSI for standards development for nanotechnologies and nanomaterials. For such standards there is often a lack of the necessary technical base for reference methods of measurement, reference materials and reference data, without which reliable standards cannot be produced by the technical committees. Currently there is no mechanism to address these needs requiring a rapid response and resolution of technical issues faced by the technical committees.

Research, Standards & Markets

As shown in Figure 1, research projects often have the primary aim of developing new and innovative products and processes, which reach the market through industry and business. R&D projects can also provide the knowledge base for developing new standards through the Technical Committees (TC) of European Standardisation Bodies and such standards facilitates access to markets of innovative products. Pre- and co-normative research ensures that standards have a rigorous science and technical basis for robustness and can be difficult to incorporate in a normal industrial R&D project. Funding for pre and co-normative research project in support of European standards and innovation requires is critical for the rapid development of standards, which must be robust.

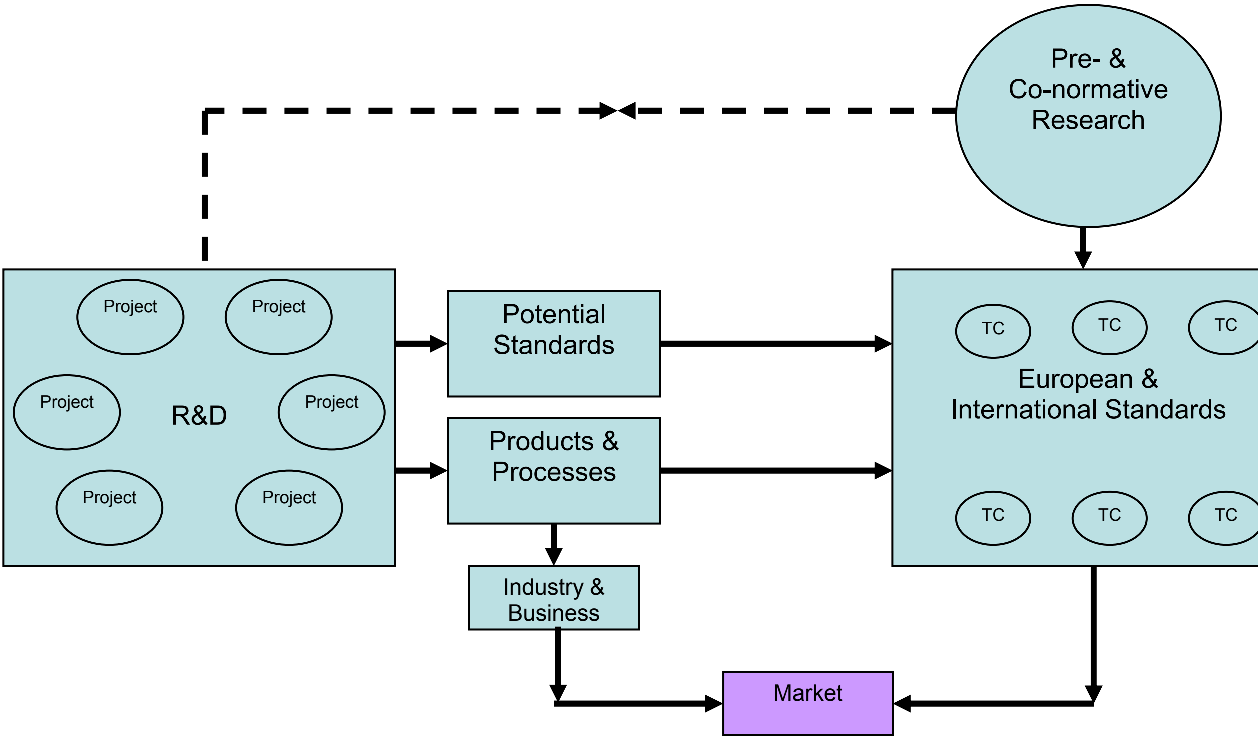


Figure 1. Relationships between R&D projects, standards and markets

Recently CEN/CENELEC have established a Research Helpdesk to support researchers and innovators in understanding and integrating standardisation in their research projects (www.cen.eu /go/research)

Best practice for linking research with standardisation at various stages of an R&D project has been recommended by CEN/CENELEC as shown in the diagram below:

STAGES IN RESEARCH, DEVELOPMENT, INNOVATION	**LINKING AND STANDARDISATION**
Developing a new project idea	Screening existing standards and needs for standards
Preparation of a project proposal	Identifying where standardisation can benefit to the project Defining how the project team will work on standardization during the project and who will be the standardisation partner
Project execution	Identifying standardisation potential of project results Working with the standardisation partner Contributing to standardisation
Protecting, disseminating and using project results	Using standards and standardisation as dissemination channels

Figure 2. Best practice for linking R&D and Standarisation (source CEN/CENELEC)

Types of Standards

Standards have a wide range of scope and interact in different ways with the innovation process. Key categories of standards are:

- Terminology standards necessary for communication between producers, users and regulators;
- Measurement & Characterisation, and Test Standards which are vital for improving performance reliability and supporting regulations;

- Specification Standards for new products and processes critical for trade and regulation;
- Interoperability standards that underpins competitiveness and user benefits;
- Standards for services, management processes which are becoming increasingly important;
- Standards for safety, quality and environmental performance for societal benefits and sustainability.

Barriers for Effective Transfer of Research Output into Standardisation

R&D carried out under the Framework Programme has a major potential to contribute to the development of reliable test and measurement methods and Standards. However, the potential is far from being realised due to a number of factors as follows:

- When a project is approved, assessment is not made reliably of the potential contribution it can make towards the development of new standards or to the improvement of existing standards;
- Timescale of research projects often not aligned with standardisation timescale. This is because once the research project is completed, there is usually no financial support available for transferring the results into written standards and securing consensus through participation in the relevant standards committee which may be European or International;
- Not all researchers wish to participate in standards committees which require meticulous attention to details and usually provide little recognition and enhancement of a research career;
- Researchers and standardisers often operate in different circles and may not be aware of each other's activities;
- Funding for pre- and co-normative research, although relatively small, is extremely difficult to find;
- Within DG RTD, there is not a focus for linking research with standardisation. Each Directorate deals with this topic within its own programme remit and interacts directly with DG Enterprise who has the overall policy responsibility for European Standards and the European Standards Organisations (ESOs - CEN/CENELEC and ETSI). DG enterprise provides financial support to ESO and can mandate ESOs for the development of standards and request DG research to support pre-normative R&D. Furthermore, Directorate B has the responsibility for a large Article 185 activity called the European Measurement Research Programme (EMRP) which covers primarily the Metrology infrastructure.

Role of metrology, standards and Environment, Health and Safety (EHS) issues for removing the barriers to innovation

In order to clearly demonstrate the challenges associated with the exploitation of research results through standardisation and the provision of the necessary scientific bases for developing robust standards, the position of EHS research for nanotechnologies is now reviewed in detail.

EU Research Activity

The European Commission has invested heavily in innovation through the NMP programme since 2003.

One of the key issues identified as a potential barrier to innovation in this area is the uncertainty concerning the impact on environment, health, and safety (EHS) of nanotechnology in general and nanomaterials (including nanoparticles, nano-objects, nanofibres, and aggregates and agglomerates thereof) specifically. Concerns about these issues first came to a head in 2004 with publication in the UK of the Royal Society and Royal Academy of Engineering Report, *Nanotechnologies; opportunities and uncertainties* (9). The key conclusion of this report was that, whilst many nanotechnologies pose no foreseeable risks to health and environment, nanoparticles and nanotubes in particular were considered to pose potential risks. This stemmed from base knowledge already known about the effects of particles, and how these effects link to particles size. Potential risks of nanotechnology, both real and perceived, have been identified as significant barriers to innovation.

In the last five or six years, the NMP programme has invested heavily in research into EHS issues. For several years now, the research community has responded by launching very valuable projects under the Sixth Framework Programme (FP6) and Seventh Framework Programme (FP7), marking significant technological progress both in the technology and in its safety management. Thirty projects are either completed or underway and represent a total RTD investment of €82.5M, from the NMP and other programmes (accounting for 11 projects under FP6 worth €30M and 19 projects under FP7 to date worth €52.5M). These projects, together with a significant number of projects supported by government resources in the EU member states and the FP7 associated states as well as other projects addressing safety as secondary objective, represent valuable efforts of the scientific and industrial research community towards addressing this important topic.

Projects have been concerned with, *inter alia*:

- Understanding mechanisms of toxicity (including ecotoxicity);
- Development of dose response relationships;

- Assessment of distribution, fate and behaviour of nanomaterials;
- Measurement of exposure;
- Development and evaluation of risk assessment methodologies;
- Consideration of life cycle issues.

Activities have included the review and definition of state-of-the-art, assessment and adaptation of existing methodologies, fundamental research, application of evolving state of the art, infrastructure development, networking, and dissemination activities.

A full list of FP7 projects, concerned with the development of knowledge concerning EHS issues and (in many cases) exemplifying this knowledge through case examples, is provided in Appendix 1. More details are available on the NanoSafety Cluster website (http://www.nanosafetycluster.eu).

There are several other FP7 projects that are more focussed on innovation (e.g. the development of new nanotechnology materials, processes or products), but which include a safety work package that draws heavily and early on emerging knowledge from this extensive EHS research programme. These projects are typically not as visible as the core research projects and the EHS component of the project is typically EHS, around 10% - 20% of the total project value. The projects are intended to provide pragmatic solutions to real development issues and provide a valuable platform on which the emerging knowledge can be tested. We estimate between 5-10 of these projects may be active at present.

International Research Activity

EU research activity needs to be seen in the context of other research being carried out worldwide. This includes research by national and international organisations, standardisation activity being carried out by CEN and ISO, the development of infrastructures that support EHS activity such as QNano, and regulatory activity in areas ranging from REACH to the environment and consumer protection.

The scope of international activity relating to nanoEHS research is summarised below in Figure 3.

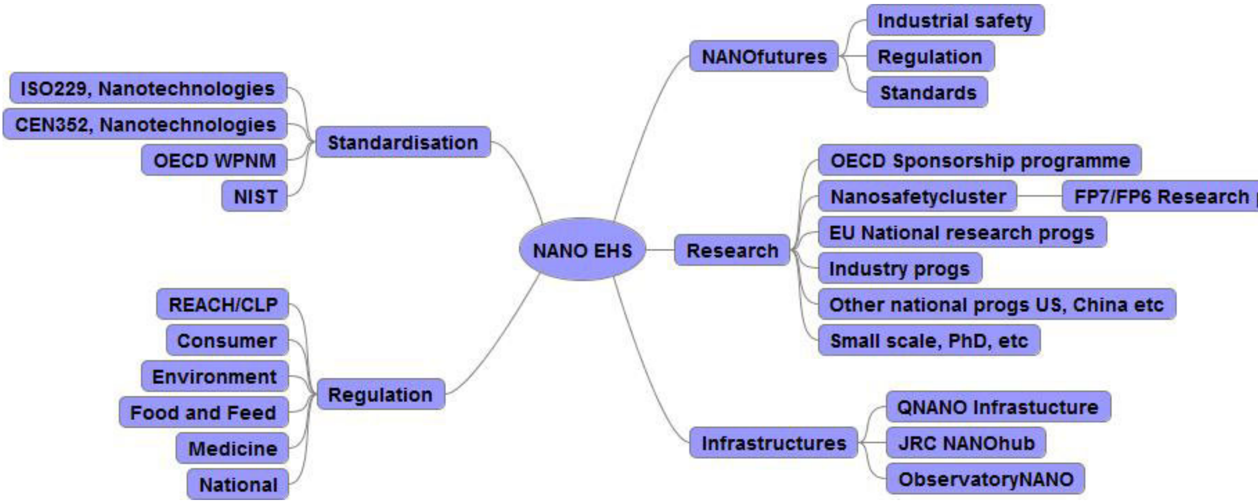


Figure 3. International activity in nanoEHS

A critical element is the integration of this activity; it is not appropriate simply to find a European solution. European researchers are highly active in international collaborations. A recent example was the Joint U.S.-EU Expert Workshop "Bridging NanoEHS Research Efforts" held in Washington on the 10th-11th March 2011, which aimed to continue the robust dialogue between the U.S. and EU on issues of shared concern pertinent to nanotechnology research initiatives. European researchers are also active in supporting and benefiting from the development of the infrastructures QNano and Nanohub, and some are involved in standardisation activity although to a lesser extent.

Regulation is outside the scope of this document and will not be considered further. However, the ability to regulate effectively, in a way to promote rather than hinder innovation, is to a large extent dependent on the availability of the scientific evidence, standards and guidance that are being produced through this activity.

EHS Measurement for Supporting Innovation

Relevance of current activity

Currently, the EHS programme of NMP research is not fully integrated into innovation-led FP7 work. Although many of these projects have industrial partners, and are working with commercial or near-commercial nanomaterials and processes, the projects are more fundamental in nature and are concerned with developing the underlying knowledge, models and tools for subsequent application in risk assessment and management. This activity is critical to underpin the knowledge base, which will provide confidence in future nanotechnology-based products and processes at some point. At the moment, however, many questions remain unanswered. Although these projects provide a direct route into the innovation process, the EHS component is typically small and they provide project-specific, rather than generalisable, solutions.

In looking to the future, the NanoSafety Cluster is developing a Strategic Research Agenda document entitled *"EU Nanosafety Community: A Vision for Safety Enabling Nanomaterial and Nanotechnology Innovation",* which is currently being drafted and will be published later in the year.

This community has assigned itself the goal to identify key areas of nanosafety research which are likely to be of special significance in the coming 5 - 10 years and for which EU-level research to provide European added value, not achievable based on Member State actions alone, is needed. The goal is also to provide not only a vision that might be achievable based on current understanding, but also one which would be extremely important to achieve if the goals set down in the Commission 2020 strategy are to be met.

Activities envisioned within the draft Strategic Research Agenda document are indicated in the text box below.

1. Promises of engineered nanomaterials: safety by design
2. New measurement principles for nanomaterial exposure assessment
3. Exposure to and life-cycle of engineered ENP
4. Nanomaterial biokinetics and translocation
5. Nano-bio-interactions
6. Identification of ENP metrics relevant for harmful health and environmental effects
7. Examination of ENP-induced pathogenic mechanisms in vulnerable populations
8. Environmental interactions of nanomaterials
9. Intelligent safety/toxicity testing strategies of ENP
10. Assessment and management of risks of ENP
11. Human field studies and epidemiology
12. Databases
13. Networking between the scientific community and the industry

Next steps

For Europe to be successful, it is necessary for the innovation process to move forward with confidence that the EHS and societal issues are being addressed and that plausible solutions are or will be available within the timeframe of the process.

To achieve this, it is necessary to link the EHS activity more clearly with the Innovation Chain concept. There are 4 elements to this:

1. Implementation of the NanoSafety Cluster strategy;

2. Development of Innovation Chain EHS projects;

3. Establishment of Centre(s) of Excellence in EHS;

4. The integration of EHS research with industry.

The NanoSafety Cluster and their strategy is a critical element within this process. Based on the early drafts available, it is their aim to facilitate routine assessment and management of risks incorporated directly into product development. A second aim is neutral and reliable dissemination of information on engineered nanoparticles by regulators, academia, as well as industry. Given the existence of significant knowledge gaps, there is a requirement for the core fundamental research programme being developed by NanoSafety Cluster to be implemented.

The second element relates to the development of what has been identified as “Innovation Chain EHS Projects”. The Horizon 2020 approach is to create a coherent set of instruments, along the whole "innovation chain" starting from basic research, culminating in bringing innovative products and services to the market.

The full Innovation Chain approach facilitates a more targeted type of EHS research to be carried out. One relevant concept is that of “Corridors for Innovation” initially described by Grobe (10). This was originally envisaged as a stakeholder dialogue concept that would develop a list of materials with a “licence to innovate” from researchers, regulators, risk assessors and civil society organisations. This would include examples of nanomaterials using a specific limited types of formulation/processing for a certain type of accepted applications which are “proven to be safe” over the entire lifecycle.

This is a powerful idea. In these ‘corridors for innovation’ the spaces to innovate will be those areas where EHS barriers have been identified and addressed. The challenge is to construct these corridors. One option for implementation would be to develop large-scale EHS projects with the purpose to identify, map, solve and act as a curator for the solutions of the EHS issues for specific innovation chains. The dimensions of these corridors would encompass the entire life cycle including development, manufacture, use, release to the environment and end of life. The type of work that would be necessary would include, *inter alia*, toxicology, exposure, risk assessment, product safety, environmental release, environmental fate and behaviour etc. This will draw heavily on the knowledge base emerging from what will become the core (fundamental) research programme foreseen in the first element The model for these projects is similar to the innovation-led projects that are currently ongoing, but at a much larger scale where the outcomes are generalisable to the whole chain rather than simply to a specific application.

A third element relates to the distributed nature of this activity. One of the main difficulties and issues with the current programme of research activity is a lack of consistency in the outputs from the projects. This has led to a plethora of different results for apparently the same materials, which are difficult to interpret. Within the community a number of activities are underway for resolving these issues. One of these is the NanoSafety Cluster, previously mentioned, which is an organic community formed around the European projects. The purpose of this community is to share information, protocols, material etc., again leading towards greater harmonisation and standardisation. Participation in this community is mandatory for all new NMP projects dealing with nanotechnology risk.. Another activity is QNano, which is a research infrastructure based on transnational activities. The focus of this, however, is on ensuring access to measurement and characterisation facilities.

One of the real challenges is the lack of funding for this type infrastructure activity and while this remains a marginal activity in relation to most projects, it is difficult to see how it will gain sufficient momentum or critical mass in order to drive forward these advantages which are potentially critical for successful innovation.

There is a therefore a need to establish a single centre, probably from a small group of institutions, to be Europe's primary repository and source of information concerning the potential risks of nanomaterials to health and the environment. This centre would have the task of capturing, interpreting and disseminating the emerging evidence and would facilitate open exchange between industry, academia, regulators and the public. From the European perspective, this centre would provide the focus and input into worldwide activity including standardisation.

The fourth element is integration with industry. In this regard, there is a critical role for the NANOfutures technology platform which, for the purposes of EHS, sits between the industrial community and the NanoSafety Cluster. The role of NANOfutures in this respect is to identify the innovation pathways, to match these against the developing strategy of the NanoSafety Cluster, and to map out programmes of work that will facilitate the clearing of these 'corridors of innovation'.

EHS in and for Standards

It is noted that the need for "standards" in the area of nano EHS is widely advocated. However, what is meant by standards in this context is not always clear and consistent. Various types of "standards" may arise from, or would be helpful, to nanoEHS projects. These include:

1. Measurement standards for characterising materials;
2. Standards for measurement methods within toxicology;
3. Standard protocol for assays;
4. Standard materials;
5. Measurement standards for estimating exposures (including concentrations in air, water, soil and other media);
6. Management standards that describe the risk assessment process;
7. Standards which convey a specific performance in terms of safety of use of a product or application.

This forms a "standardisation chain". To support innovation, the standards that be of most value are probably the latter two. These would provide confidence that a product can be manufactured and used within a framework in which the risks were quantified and controlled. Successful development and implementation of this framework, however, could only be built from the earlier parts of the chain.

The projects described in the previous section (and listed in Appendix 1) have both a need for standards and the possibility to provide such standards. In practice, however, the contribution of these projects towards standardisation activity thus far has been rather limited. There is also a lack of integration between the researchers involved in these projects and the established standardisation community. There are a number of reasons for this. Although a number of projects have standardisation as an identified activity, this is often quite peripheral to the main objectives of the study. In many cases the studies are involved with investigating fundamental mechanisms of harm or the relationships between dose and response, which although informative, are too upstream within the chain. To some extent this is changing, with more recently funded projects placing a greater emphasis on the aspect of standardisation.

The second contributing factor is the project duration. Input to standards would most frequently come towards the end of project. However, once the project is completed, the projects no longer have continuation of funding or a programme of activity to support development of a standard.

Recommendations on the way forward

There is clear evidence in the published literature, including numerous Communications from the Commission, that metrology and standards can play a vital role in facilitating innovation based on new technologies. However, the research, metrology and standards interfaces are complex and multi-dimensional. The major challenge is to integrate R&D activities for the development of products and services with the establishment of the necessary measurement framework and tools as well as standards. This is vital for removing uncertainties in the market, establishing risks associated with innovative products and supporting trade and regulations on a global basis.

Our recommendations for action on standards and metrology are detailed below.

General recommendations

- Identify and prioritise standards need and relevance for all project proposals;

- Foresight type projects supported by DG Research should be made more rigorous with validated outputs so that recommendations for metrology, as well as pre- and co-normative research, in support of standards may be included in calls;

- Identify measurement tools and techniques with the potential to make major impacts on innovation in new technology based products and processes;

- Support access to measurement and characterisation expertise and facilities for SMEs developing products and processes based on new and emerging technologies;

- Include standards and standardisation as a selection criteria for research projects;

- Include transfer of results into standards committees as a work package where possible, or develop an additional support measure beyond the research phase;

- Ensure the use of standards and standardisation as an important means for dissemination when appropriate;

- Use resultant standards impact as a measure of performance indicator;

- Develop a single point of focus for metrology and standards within DG Research with appropriate linkages to all project managers as well as DG Enterprise, CEN/CENELEC and EMRP manager;

- Establish an effective platform for exploitation through standards and for the provision of advice, training and practical support e.g. standards drafting. The platform should use modern IT tools as well as direct support through consultancies. This could be a standards network for researchers.

EHS recommendations

In relation to EHS metrology, our recommendations are intended to push forward fundamental and applied research on the key questions, to further focus that on innovation pathways, to provide Centres of Excellence in EHS issues to act as resources and repositories, and to maximise integration with the industrial process. The recommendations are as follows:

- Implementation of the NanoSafety Cluster strategy;

- Development of Innovation Pathway EHS projects;

- Establishment of Centre(s) of Excellence in EHS;

- The integration of EHS research with industrial priorities through the NANOfutures activity.

Specifically in relation to standards, to underpin the development of this “centre” would require *inter alia*:

1. Specific funding for translational work to enable continuation after a project has finished to support the development of standards arising;

2. Development of common databases for information sharing with specific funding to develop the underlying data structures e.g. for toxicity or exposure data.

It is important also to consider that all of the work currently underway is concerned with first generation nanomaterials. Translation of this work and consideration of second, third and fourth generation needs to be prioritised.

Acknowledgement: Contributions and comments from many colleagues in the NMP Advisory Group have provided very helpful guidance in the preparation of this paper.

References

1. NIST (2006) "An assessment of the United States Measurement System: Addressing Measurement Barriers to Accelerate Innovation", NIST Special Publication 1048, Gaithersburg, MD (available at: http://usms.nist.gov).

2. COM (2010) 546. "Final "Europe 2020 Flagship Initiative Innovation Union".

3. COM (2010) 614. "An Integrated Industrial Policy for the Globalisation Era Putting Competitiveness and Sustainability at Centre Stage".

4. COM (2010) 245. "A Digital Agenda for Europe".

5. COM (2011) 78 final. "Review of the "Small Business Act" for Europe".

6. COM (2008) 133 final. "Towards an increased contribution from standardisation to innovation in Europe".

7. COM (2011) 311 final. "A strategic vision for European standards: Moving forward to enhance and accelerate European economy by 2020".

8. CEN Integrated Approach for Standardisation Innovation and Research (available at:

http://www.cen.eu/cen/Services/Innovation/STAIR/Pages/default.aspx)

9. The Royal Society & The Royal Academy of Engineering (2004). "Nanoscience and nanotechnologies: opportunities and uncertainties", The Royal Society (available at http://www.nanotec.org.uk/finalReport.htm)

10. Grobe, A. (2011). "Corridors for Innovations: Safe Design", Euronanoforum (Available at: http://www.euronanoforum2011.eu/antje-grobe).

Appendix – Nanotechnology EHS projects in FP7

Project Acronym	Full Name	Tim e-scale	Coordinating Organisation	Website
MARINA	Managing the Risk of Engineered Nanoparticles	2011 - 2015	Institute of Occupational Medicine, Edinburgh, UK	http://www.marina-fp7.eu/
ElectroGraph	Graphene-based Electrodes for Application in Supercapacitors	2011 - 2014	Fraunhofer-Gesellschaft zur Foerderung der Angewandten Forschung e.v, Germany	http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=1&CAT=PROJ&QUERY=013146bb0a24:6d10:56ddeb32&RCN=99100
NanCore	Microcellular Nanocomposite for Substitution of Balsa Wood and PVC Core Material	2008 - 2012	LM Glasfiber A/S Denmark	http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=1&CAT=PROJ&QUERY=013146c6ea03:c4dc:57b0527e&RCN=88798
InLiveTox	Intestinal, Liver and Endothelial Nanoparticle Toxicity – Development and Evaluation of a Novel Tool for High-throughput	2009 - 2012	Centre Suisse d'Electronique et de Microtechnique Switzerland	http://www.inlivetox.eu/

	Data Generation			
NanoTEST	Development of Methodology for Alternative Testing Strategies for the Assessment of the Toxicological Profile of Nanoparticles used in Medical Diagnostics	2008 - 2012	Norwegian Institute for Air Research Centre for Ecology and Economics	http://www.nanotest-fp7.eu/
ENNSATOX	Engineered Nanoparticle Impact on Aquatic Environments: Structure, Activity and Toxicology	2009 - 2012	Centre for Molecular Nanoscience (CMNS), University of Leeds, UK	http://www.ennsatox.eu/
ENPRA	Risk Assessment of Engineered NanoParticles	2009 - 2012	Institute of Occupational Medicine, Edinburgh, UK	www.enpra.eu
ENRHES	Engineered Nanoparticles: Review of Heath and Environmental Safety	2008 - 2009	Edinburgh Napier University, Edinburgh UK	http://www.safenano.org/Research/OurProjects/ECSupportedProjects.aspx

HINAMOX	Health Impact of Engineered Metal and Metal Oxide Nanoparticles: Response, Bioimaging, and Distribution at Cellular and Body Level	2009 - 2012	Asociacion Centro De Investigacion Cooperativa En Biomateriales Spain	http://www.hinamox.eu
NANEX	Development of Exposure Scenarios for Manufactured Nanomaterials	2009 - 2010	Institute of Occupational Medicine, Edinburgh, UK	http://www.nanex-project.eu/
NANODEVICE	New and innovative concepts and methods for measuring and characterizing airborne ENP with novel portable and easy-to-use devices	2009 - 2013	Finnish Institute of Occupational Health	http://www.nano-device.eu/
NanoFATE	Nanoparticle Fate Assessment and Toxicity in the Environment	2010 - 2014	Centre for Ecology & Hydrology, Natural Environment Research Council United Kingdom	http://www.nanofate.eu
NanoHouse	Life Cycle of Nanoparticle-based Products used in House Coating	2010 - 2013	Commissariat à l'Energie Atomique et aux Energies Alternatives France	http://www-nanohouse.cea.fr

NanoImpactNet	European network on the health and environmental impact of nanomaterials	2008 - 2012	Institute for Work and Health, Switzerland	http://www.nanoimpactnet.eu/
NANOMMUNE	Comprehensive Assessment of Hazardous Effects of Engineered Nanomaterials on the Immune System	2008 - 2011	Karolinska Institute Sweden	http://ki.projectcoordinator.net/~NANOMMUNE
NanoPolyTox	Toxicological Impact of Nanomaterials Derived from Processing, Weathering and Recycling of Polymer Nanocomposites used in Various Industrial Applications	2010 - 2013	LEITAT Technological Centre Spain	http://www.nanopolytox.eu
NanoReTox	The Reactivity and Toxicity of Engineered Nanoparticles: Risks to the Environment and Human Health	2008 - 2012	Natural History Museum, London United Kingdom	http://www.nanoretox.eu/
NanoSustain	Development of sustainable solutions for nanotechnology-based products based on hazard characterisation and LCA	2010 - 2013	NordMiljö AB Sweden	http://www.nanosustain.eu/

NEPHH	Nanomaterials-related Environmental Pollution and Health Hazards Throughout their Life-Cycle	2009 - 2012	Ekotek Ingenieria y Consultoría Medioambiental S.L. Spain	http://www.nephh-fp7.eu/
NeuroNano	Do nanoparticles induce neurodegenerative diseases? Understanding the origin of reactive oxygen species and protein aggregation and mis-folding phenomena in the presence of nanoparticles	2009 - 2012	Centre for BioNano Interactions, University College Dublin Ireland	http://www.neuronano.eu/
EURO-NanoTox	European Centre for Nanotoxicology	2007 -	BioNanoNet Forschungsgesellschaft mbH, Graz, Austria	http://www.EURO-NanoTox.eu
ModNanoTox	Modelling nanoparticle toxicity: principles, methods, novel approaches		Natural History Museum, London, UK	tbc
NanoLyse	Nanoparticles in food: Analytical methods for detection and characterisation	2010 - 2012	RIKILT-Institute of Food Safety, The Netherlands	http://www.nanolyse.eu
Nano transkinetics	Modelling the basis and kinetics of nanoparticle cellular interaction	2011 - 2014	Centre for BioNano Interactions, University College Dublin	http://www.nanotranskinetics.eu

	and transport		Ireland	
NanoValid	Development of reference methods for hazard identification, risk assessment and LCA of engineered nanomaterials	2011 - 2014	NordMiljö AB, Sunnemo, Sweden	www.nanovalid.eu
NHECD	Creation of a critical and commented database on the health, safety and environmental impact of nanoparticles	2008 - 2012	Tel Aviv University, Israel	http://www.nhecd-fp7.eu
SIIN	Safe Implementation of Innovative Nanoscience and Nanotechnology	2011 - 2014	Forschungszentrum Jülich GmbH, Berlin Bureau, Germany	
Nanosafe 2	Safe Production and use of nanomaterials Integrated Project	2005 - 2009	Commissariat à l'Energie Atomique et aux Energies Alternatives France	http://www.nanosafe.org

V. Key Enabling Technologies (KETs) of interest to the NMP theme

Jens Neugebauer, Livio Baldi, Kamal Hossain, François Mudry, Dietmar Göricke

Introduction

The Communication of the Commission on Key Enabling Technologies (COM(2009)512)) identifies nanotechnology and advanced materials as strategically relevant technologies, given their economic potential, contribution to solving societal challenges and knowledge intensity. The paper on KETs will briefly survey current activities in enabling technologies, show links to the current NMP activities and identify gaps – that is, key enabling technologies that are critical for further advances in areas of interest and are not receiving enough attention. It should also identify any barriers inherent to these sectors, including skills. It complements also the paper on interactions between academia and industry, by looking at specific technologies.

Basis of the work will be the findings of the Working Groups, contributing to the High-Level Expert Group on Key Enabling Technologies. Thus, their results will be reflected with special emphasis on the possible implementation at activity level rather than topic level for the remaining FP7 working program. For this purpose, the main findings of the KET-HLG working groups will taken from the reports and listed.

As an enhancement of the above mentioned methodology, also the report on Materials for Key Enabling Technologies will be taken into account. This report is the result of a joint effort of the European Materials Research Society (E-MRS, Strasbourg, www.european-mrs.com) and of the Materials Science and Engineering Expert Committee (MatSEEC) of the European Science Foundation (ESF). The report has been prepared on the occasion of the Key Enabling Technologies (KETs) initiative launched by the European Commission to give an overview of the current status and recommendations on the role Materials Science and Engineering should play in Europe for key enabling technologies.

Definition of Key Enabling Technologies (KETs)

KETs are knowledge and capital intensive technologies associated with high research and development (R&D) intensity, rapid and integrated innovation cycles, high capital expenditure and highly-skilled employment. Their influence is pervasive, enabling process, product and service innovation throughout the economy. If they are of systemic relevance, multidisciplinary and trans-sectorial, cutting across many technology areas with a trend towards convergence, technology integration and the potential to induce structural change. KETs can assist technological leaders in other fields to capitalise on their research efforts.

High level Group on Key Enabling Technologies

The HLG KET was launched on the 13th of July 2010, with twenty-six HLG Members consisting of representatives from European Union (EU) Member States, relevant European industry including small and medium enterprises, research technology organisations academia and the European Investment Bank. The remit of the HLG was to:

- Assess the competitive situation of the relevant technologies in the EU with a particular focus on industrial deployment and their contribution to address major societal challenges;

- Analyse the available public and private R&D and innovation capacities for KETs in the EU;

- Propose specific policy recommendations for a more effective industrial deployment of KETs in the EU.

Phase 1 Activities of the HLG on KET

In the first phase, the HLG KET outlines the potential impact of KETs on grand societal challenges and the competitiveness of European industry. Six Key Enabling Technologies were elaborated:

- Photonics
- Manufacturing
- Nanotechnologies
- Biotechnology
- Advanced Materials
- Micro/Nanoelectronics

A SWOT analysis of KETs and current challenges for KET value chains in the EU and beyond, in the context of global competition, along with an initial vision of the way forward. This vision recognises that those nations and regions mastering KETs will be at the forefront of future advanced and sustainable economies integrating cutting-edge technologies into their manufacturing and service industries and managing the shift to a low carbon, knowledge-based economy, and ensuring the welfare, prosperity and security of their citizens . A special emphasis is given on the "Valley of death" problem in the innovation chain. Main pillars to bridge the gap will be described and potential actions on the pillars will be proposed.

Phase 2 Activities of the HLG on KET

The development of appropriate policy recommendations will be the goal of the second phase of this HLG KET initiative, which will look at how existing instruments at EU and national level can be better aligned and utilised for the deployment of KETs." To accomplish this work, seven working groups have already been identified with their remit as outlined in Appendix A. A full report will be delivered by the HlG KET President and Board in July 2011.

WG 1: KETs transdisciplinarity.

Most innovative products combine several KETs simultaneously, each KET bringing a piece of innovation resulting in a more innovative product as a whole. It is therefore important to assess the value-added of an interdisciplinary KETs approach, and to deliver proposals likely to facilitate such interdisciplinarity. Particular attention should be paid to the development of skills, education and training systems compatible with such interdisciplinarity as well as formats for disseminating current technological knowledge to industry.

WG2: KETs Value chain and vertical integration.

Innovation has to start simultaneously at various stages of the value chain: in order to speed up innovation in Europe, the traditional modus operandi needs to be complemented with an approach that brings together and stimulates innovation at key stages of the value chain simultaneously, in order to create competition and breakthrough for comprehensive solutions. The various contributions received during phase 1 of the HLG clearly identified the necessity to assess the KETs value chain from KETs to final product to identify and follow-through on opportunities for KETs integration in other established or new value chains as well as KETs contribution to addressing grand societal challenges.

WG 3: KETs Technological Research enhancement.

This working group shall focus on the first pillar of the KETs bridge to pass through the "valley of death"; the development of core technologies by European technology research organizations, in close collaboration with industry speeding up feedback loops aimed at shortening time-ta-market. It shall work on key measures to reinforce technology research in Europe through technology transfer and intellectual property measures, the strengthening and launching of flexible public private partnerships involving innovative multinational companies, SMEs, academia, government research agencies and government sectors, as well as joint strategic programming activities.

WG4: KETs Product Development launch.

This working group will define the various demonstration activities required in Europe to further deploy KETs. It will include focusing both on pilot lines, scale up and large scale deployment demonstrators for KETs open to small and large companies in a variety of applications. The main objective will be to create the success conditions for Europe to remain competitive with respect to American and Asian competitors. The working group will then be tasked with the identification of the key measures required to succeed in the launching of such activities.

WG5: KETs Globally competitive manufacturing facilities installation.

This working group will address policy and other issues concerning the conditions for establishing competitive production capacities in Europe, able to compete with international facilities, in particular those in East Asia.

WG6: Policy benchmark and options.

European industrials willing to strengthen and *I* or install pilot lines or production plants always face various options for their localisation throughout the world. One strategic issue for Europe is to make Europe the obvious place for such investments. To improve current framework conditions, it is essential to benchmark positive deployment policy frameworks and strategies across the world and within Europe on issues such as European internal market, competition and trade policies, support of investments, state aid policies, R&D activities, tax incentives, public procurement, skills development and training activities, trade, market pull (e.g. lead markets), skills and public-private engagements.

WG7: KETs Financial instruments.

Launching European initiatives to recover a leading role at a global level will imply a considerable financial effort from the public and private sectors. The public sector will have to combine several horizontal sources of EU funding reflecting the recognition given to the role of KETs in the framework of Europe 2020 Agenda, together with several sources of vertical funding provided by regions and Member States. This public support will subsequently leverage private funds, with the total combination of investments enabling Europe to address in parallel the two major KETs challenges, the continuous improvement of technological capabilities and the improvement of production capacities in Europe.

Preliminary Results and Recommendations of the High Level Group

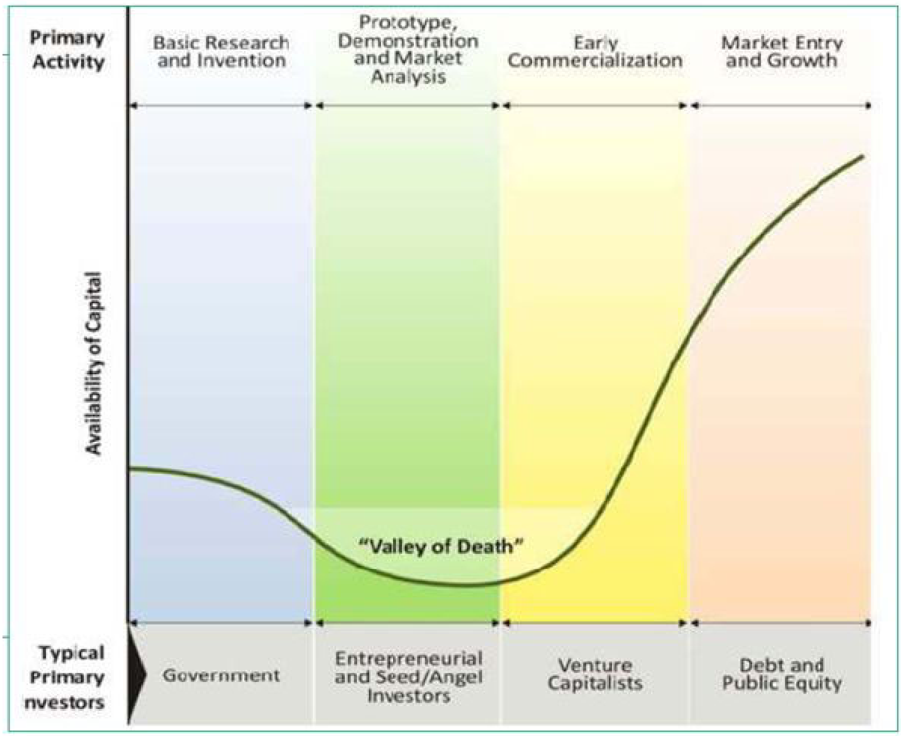
Key enabling technologies (KETs) as defined by the European Commission:

- are research & development-intensive

- are capital-intensive
- require a highly-skilled work force
- are subjected to rapid innovation cycles.

Due to their multi-disciplinary and trans-sectoral characteristics and their trend to convergence and integration at the industrial deployment level they are often emerging and converging technologies.

Six key enabling technologies were chosen, microelectronics, industrial biotechnologies, nanotechnologies, photonics, advanced materials and advanced manufacturing. Tasks are to identify commonalities restricting the deployment of KETs in Europe and to make recommendations how to enhance technological research in their fields and how to enable subsequent stages of "proof of concept" demonstrators and a large scale deployment for production in Europe. In the first stage of work by the High Level Group on Key Enabling Technologies contained vertical analyses of KETs and extracted commonalities. In the mid-term report a picture was sketched containing a “valley of death” between applied research



and the production “ramp-up” stages after prototyping. This gap in the innovation chain was identified to be specifically severe (i.e.: wide) in Europe.

Several cases had been elaborated, where this valley of death applies:

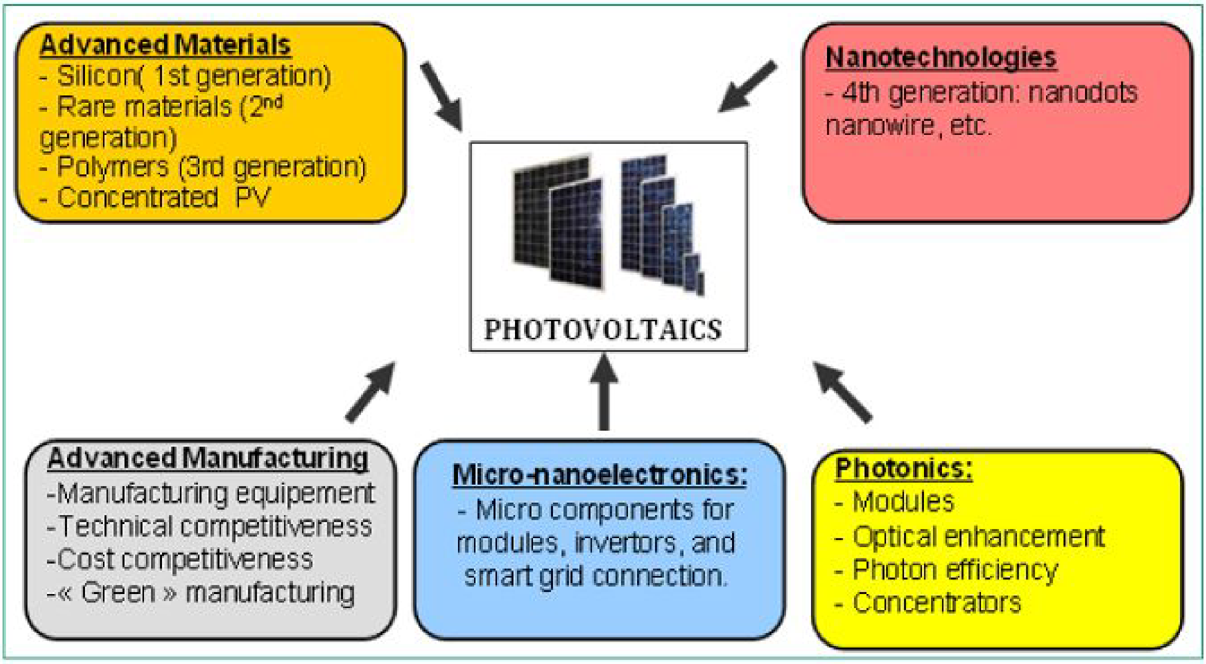
a) Solid State Lighting

b) Nanoelectronics

c) Advanced Batteries

d) Industrial Biotechnology

e) Photovoltaics



The need for an integrated strategy for KETs development is found to be crucial

The KETs sectorial SWOT and value chain analysis, as shown in the report, highlight the need for an integrated KET approach. Owing to the interdependency of KETs in the development of advanced products, it is seen to be essential to propose an integrated KET approach covering the spectrum of all the KETs. This shall provide significant added value to strengthen their development and deployment in and from Europe.

The photonics example shown above demonstrates that a number of KETs are required to develop photovoltaics based products. In fact, for each subsequent PV generation, the number of KETs to be combined increases. The third generation of PV products will include nanotechnology, advanced materials along with microelectronic devices. Due to the different degree of KETs maturity, it is essential to propose an integrated KET approach covering the different development phases. The KETs sectorial SWOT and value chain analysis has identified a double condition for sustainability: technology capability and manufacturing capacity:

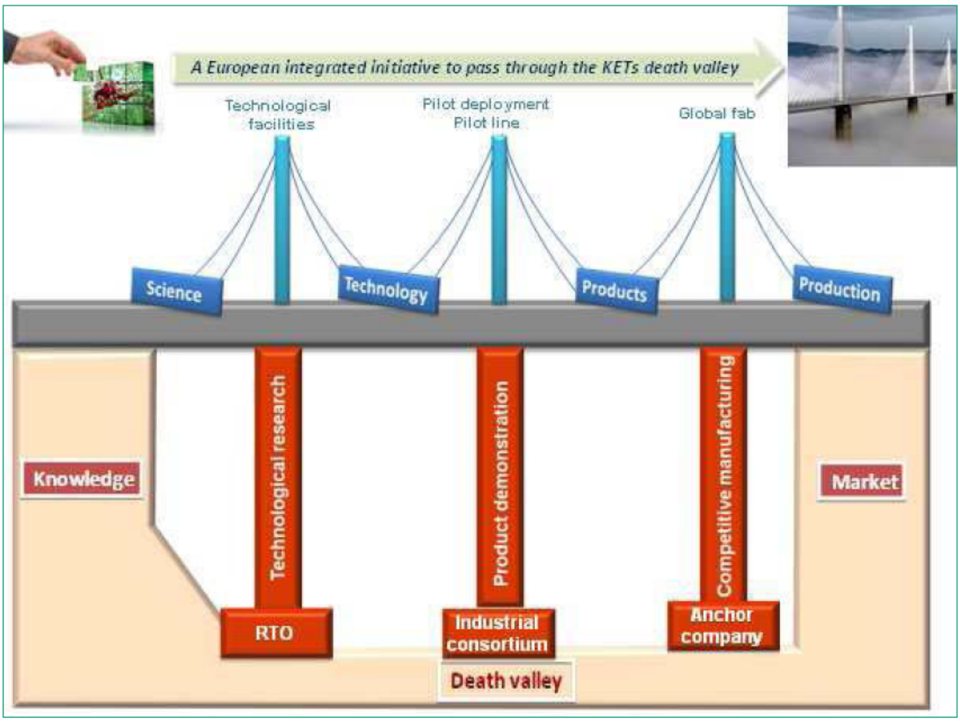
To be world competitive requires both a technology capability and manufacturing capacity.

Therefore, KETs competitiveness improvement must follow two combined routes within the overall KETs integrated strategy:

~ improving technology capability mainly supported by public investment

~ improving manufacturing capacity primarily supported by private investment.

A so-called three-pillar-bridge was suggested as a way forward. Pillar 1 addresses how to enhance technological research. Pillar 2 addresses how to facilitate pilot lines, demonstrators and prototyping. Pillar 3 addresses how to stimulate large-scale production in Europe. This "three-pillar-bridge" is also referred to as the "KET innovation bridge".



In the second phase of the HLG work, the aforementioned working groups were established.

At the time of preparing this report, the results of the working groups in phase 2 were only available in draft version. However, the preliminary results are not on an action level suitable for implementation in the remaining program of FP7. In the following, reference is made to the results of phase 1, specificly in the six elaborated key enabling technologies. The results of the working groups are in the Annex I of this document. One of the six working groups, the group for manufacturing concentrated more on an analysis on the current state of technologies rather than concluding with recommendations. Thus no recommendations from the manufacturing group are in this results summary report.

Identified gaps in FP7 and recommendations

From the given reports and results the following conclusions can be made:

As a European weakness, excellent research results in the fields of key enabling technologies too often don't lead to a successful market entry of European industry. The picture of the "Valley of Death" is used to describe the dilemma.

The midterm report of the KET-HLG makes specific reference to the following cases, where the "Valley of death" problem arises:

a) Solid State Lighting

b) Nanoelectronics

c) Advanced Batteries

d) Industrial Biotechnology

e) Photovoltaics

To overcome the Valley of death, three pillars have to be considered:

1) Excellent technological research is crucial

2) Pilot lines and demonstrators are important for product validation

3) Competitive manufacturing needs to be fostered by large scale manufacturing abilities

Integration activities are considered to be essential for enhanced KET development

Recommendations

As a consequence, it is likely that in the future, especially for the implementation of the CSF after FP7, more emphasis will be given on pilot activities and demonstrators.

- FP7 provides already instruments to support this type of actions within e. g. cooperation projects is the possibility to **support demonstration type activities**. Also the development of pilot lines are possible. Taking the results of the KET working groups into account, a more intensive use of this instrument/funding category should be encouraged. To get enough impact, especially **large scale integrating projects should be considered**. Experiences for the future CSF implementation could be gained as well by enhancing demonstration activities.

- It is felt that the given results so far from the KET HLG are not justifying a very specific recommendation on technological research, which could be implemented on action level in the upcoming calls of the remaining FP7 program. It can be stated that there is a good coverage of the discussed KET topics on technological research within the actions of the FP7 work programmes in the years 2007-2011. (See also the complete liste of NMP topics in FP7 from 2007 to 2011). A priorisation of suggested actions seems not to be possible from the given reports.

- Also, as a conclusion of the summarised results, more emphasis should be spend in the integration part of the NMP-program (currently activity 4.4) The commission should consider not only to enlarge the share of the budged in this part but also to use this measure more intensively as a strategic activity line. So far the activity type "integration" seems more to be a pool of topics which do not fit directly into the activities in Nano, Materials and New Production.

Annex – Recommendations from HLG KETs Working groups and from the E-MRS/MATSEEC Report

Results from KET Working Group Photonics

In their report, the working group made the following recommendations:

1. Launch pilot-scale deployment programs of >€100 million each in five photonics areas to use photonics innovations to leverage the EU infrastructure and create jobs

Most EU innovations fall through in the stage between successful research and initial market deployment – the EU lacks both the US venture capital/business angel network and the Chinese government intervention to support the implementation of innovation. Pilot programs that generate market pull of sufficient size to justify scaling up an innovation resolve this.

The best way to get value for the EU in photonics is to use it to leverage the EU infrastructure, thereby making all 500 million people in the EU more competitive rather than just the people involved in the photonics value chain. This also results in the innovation benefits resulting from the deployment of photonics, staying in the ground in the EU rather than being exported.

Moreover successful pilots create demands that in turn accelerate market penetration and are thus a driving force for more jobs.

We propose **five pilot-scale programs**, of a scale of > €100 million each:

- Solid-state lighting – EU SSL alliance. To demonstrate cost effectiveness and energy efficiency of Solid State Lighting in various European cities for indoor and outdoor general lighting applications and thus take the lead of the transition to this new era of lighting.

- High-throughput PV processing - non-contact laser-based processing of advanced, high-efficiency cells and modules.

- Equipping hospitals with photonics-based, early-detection cancer diagnostic systems. To allow earlier detection of cancer in >100 hospitals, a major social and economic impact for the EU

- High-speed telecom infrastructure – the digital village. To demonstrate advanced Web 2.0 and 3.0 products and services in multiple village-scale pilot programs (>100,000 people) with ultra high speed fiber networks

- Sensor networks initiative. To demonstrate open wireless autonomous sensor networks (data and power) which will bring a radical breakthrough in sensor based applications.

These actions would be supported by existing and new photonics centres of excellence providing the essential technical and innovative supporting expertise. - Specifically a Virtual Centre of Excellence for Green Photonics is proposed to stimulate exchange of knowledge and infrastructure between the different relevant fields of green photonics, targeted at major challenges in material, device and process simulation.

2. Set up EU-backed funds to facilitate access by photonics start-ups to capital, in the form of grants that leverage private-sector investment

A large proportion of photonics innovations are in SMEs (or hidden in university research) where risk money is missing to commercialize the research – the EU has a very underdeveloped venture capital infrastructure.

Establishing a EU fund to leverage existing private capital in photonics provides sufficient financial incentive for private capital to invest in commercializing EU photonics innovations.

3. Establish a KET-focussed EU R&D financing arm that provides financing for KET projects

The current EC system for supporting R&D stops at the precompetitive R&D stage (often long-term science) and allows innovations to die before the all-important scale up to manufacturable prototype. Also the initial proposals are too voluminous and the timelines for selection are too long for most SMEs to count on, and the awardees too numerous to lead to an efficient decision process.

We propose a new fund that, initially for KETs alone, is allowed to operate with streamlined, more market-oriented rules, and aiming at shorter-term results involving prototype development. If proven to be more successful, this could eventually be expanded to other areas. This funding mechanism would be more market-driven than the current financing approach, namely ending in a manufacturable prototype rather than stop at precompetitive R&D, and would be faster and more streamlined with shorter time-to-outcome.

4. Use public procurement to foster deployment

The use of public procurement to support commercialization of innovations will be critical; through public procurement governments are in a position to act as a catalyst through procuring innovative solutions for societal needs such as health or energy efficient products, etc. Currently public procurement makes up 17% of European GDP, but the use of this instrument to embrace innovation in Europe has yet to be seriously explored.

Results from KET Working Group Nanotechnologies

In the following, the report of the working group provided the following statement and recommendations:

Nanotechnology is a very diverse, naturally multidisciplinary cross-cutting concept covering a wide range of developments from new approaches for the development of new materials and structures with tailor-made unique properties. The emergence of nanotechnology has potential implications for the creation or refinement of a wide range materials and devices with applications across society from medicine and electronics to materials and energy related topics (storage, saving and transportation). Many of these applications with Improvements of products and processes can be ready for the market trials and penetration in the next 5-10 years.

Undisputed is the big potential from nanotechnology to employment and societal solutions.

Nanotechnology is used as a major driver for the trend to improve existing products by creating smaller components and better performance materials, all at lower costs. In this segment nano·companies will grow rapidly (especially building on Europe strength to have a well functioning network of small, medium and large sized companies) and thus ensure continued high employment in area where EU industries are traditionally world leaders (i.e. materials, consumer, automotive and ICT). The minute scale of the system components alone enables the realisation of novel functionalities and properties for improving existing products and applications or developing new even disruptive ones.

As an "enabling technology" , nanotechnology is key in the value chain, being used to realise smaller, quicker, more powerful, or more " intelligent" intermediates and systems components for products with significantly improved or even completely new functions.

The main challenges is that there is no single nanotechnology industry and hence the continuum from successful quality research to useful products needs not only to encompass the significant "research" gap from academia to industry, but requires wide scale cooperation in/along many different value chains and between various Industrial sectors before this KET can fulfil its potential usefulness for society.

Significant opportunities will arise if Europe is able to bring together value chains from different industry sectors to interact with each other in a meaningful way to create new products and applications at the interface of their traditional domains and if this is supported by complementary cross-border and cross-institutional public policies.

The value and impact of nanotechnology today and in the future is the subject of much research and produces a wide variety of figures. According to studies nanotechnology impacted US$254 billion worth of products in 2009. This impact is forecast to grow to perhaps US$2.S trillion by 2015.

Nanotechnology offers a large potential to impact on employment and to provide solutions for major societal challenges. It is important in this context that nanotechnology is a major contributor to keep employment figures at high level in sectors, in which the EU is among global leaders. For specific nano related businesses employment estimates show that in 2008 there were 160000 workers in nanotechnology globally. Representing a 25% increase from 2000. Assuming this trend is increasing by 2015 two million new jobs should be created by this technology globally.

Building on Europe's strength in having a well-balanced 'and well-functioning network of small, medium and large sized companies can allow optimised value chain interactions. This is especially important due to the potential impact of nanotechnology on established industries and markets by introducing technological innovations to economically important sectors with an orientation towards "value-added" value chains. Many opportunities will arise if Europe is able to bring together different industry sectors to interact with each other in a meaningful way to create new products at the interface of their traditional domains.

Europe should not always look to Asia where the current technology solution is being produced, but look for areas where technology deployment is characteristically complex. Solving such complex challenges is a strength with a European 'mindset' on implementation of technology.

The basis for a successful deployment of nanotechnology in the US and Germany is the excellent cooperation and synergy between various national ministries and public bodies. This is key to get added value through innovation and solutions from the invested public and private funds.

Nanotechnology needs to cross traditional boundaries such as cross border funding. This is especially needed for smaller member states, in order to achieve a critical mass for the above mentioned cooperation. Cross border funding should be made available to support projects which bring together development prototyping ventures with multiple companies from various sectors along the value chain in the same way that FP programmes bring together for research.

There is the need for a consistent and coherent EU strategy for the deployment of nanotechnology across all Member States and along the various value chains. The target should be to create a favourable framework for technology, innovation, regulation and governance that facilitates knowledge transfer and utilisation. Currently, there are clear risks associated with deployment of nanotechnologies and nanomaterials because of the uncertain regulatory environment and investment and trade implications. As a major step in the safety debate a new approach is currently being discussed between Member States and the EC

for targeted safety research. This involves a public fund to finance the research that is needed for practical decision making which has to complement basic research that in many cases creates more questions than answers.

The benefit-risk discussion in specific application areas should guide future policy including funding and governance. The new EC strategy to link societal challenges with technology and have a parallel safety discussion on specific uses as a techno-socio-economic innovation ecosystem should be a step forward to the timely delivery of the smart and green growth objectives of the 2020 agenda.

A pragmatic proposal is that new nanomaterials should be evaluated along specific value chains in their respective different use categories and the level of protection required assessed using regulations that are already in place. A too rigid precautionary regulatIon approach runs the danger of significantly reducing the its adaption in Europe, while not avoiding the risk coming from it's adaption with products from other less controlled areas of the world.

It is key that the private and public sectors have to develop common risk- benefit messages targeted for specific applications of nanotechnology towards societal challenges. This forms the basis for the urgently needed broad dialogue with the public about benefits in everyday life (including the economic risk of not exploiting the technology for Europe) as well as the around safety concerns Manufacturing for new nanomaterials and their introduction into the value chain as the basis for the technology is a challenge. Countless new nanomaterials have been synthesised in laboratories worldwide, opening up the potential for a wide variety of new applications. However, new exciting materials often remain at the laboratory stage, because the road from fundamental science to end·systems production is very complex.

The deployment of nanotechnology is key for Europe to strengthen its manufacturing capacities while addressing societal challenges, through a rejuvenation of manufacturing technologies, processes and products as well as through creation of new business. Development of new applications and materials will require new unit operations as well as the clever combination of new and existing processes . Up-scaling is critical In the development of any new process In order to achieve mass production of nanomaterials, multipurpose plants will have to be developed.

Europe has strong basic research and an elaborate landscape, significant interest from the new generation and a good industrial base for the exploitation. The "back· bone of the deployment is the excellent symbiotic network of smaller, medium and large companies as well as the presence of major full value chains in Europe within a smaller area than e.g. in

Asia-pacific region, enabling cooperation for deployment. Difficulties still are in utilisation, difficulties for start up's, information deficits in commercialisation of research and fragmentation both in research and innovation landscape across Europe Information, education and training of markets players are key parameters for the integration of new materials and technologies in the different value chains. This is relevant for appropriate skills in the workforce of various different sectors, technology education, modern specific equipment to manufacture and process this technology. Smaller enterprises need to be able to easily understand the precise allocation of responsibilities at EU and country level. Existing support structures are, in general, too complex despite efforts to simplify and make them SME-friendly.

Nanotechnology is by definition a technology that requires integrated approaches involving a variety of scientific, technical and engineering disciplines. Furthermore the development of resource efficient processes require efficient interlink between natural sciences and engineering. For the development of converging technologies multidisciplinary skills will be critical. There is the need to provide future engineers and scientists with a multidisciplinary and broad skill set and educate them in sufficient numbers to deploy not only nanotechnology, but also the integration of this into other areas.

A true market push initiative can only be successful in markets where Europe is traditionally strong (for example automotive, aerospace and consumer) as there will be no distinct " nano-industry" sector as such that is able to achieve critical mass and a unique end·market. Thus for the successful deployment of nanotechnology it is crucial that EU Innovation policy is complemented and integrated with EU Industrial Policy to ensure Europe can fulfil its potential for leadership at global level. Regarding financing hybrid public - private financing models can be a way to fill the current Investment short fall in Europe.

Due to the character of nanotechnology, it is essential to put industry first to create a demand pull, instead of trying to induce a science push.

Nanotechnology can contribute towards many societal benefits. Therefore a target-oriented procurement market that can describe concrete targets for products and processes without being over prescriptive is required. The countries that are currently the most successful In the exploitation of nanotechnology like US and Germany are those which have a "super customer".

Results from KET Working Group Biotechnology

Identification of Essential Further Research Priorities

In order to make full use of the biomass, for food as well as for non-food applications, it is important to develop efficient and robust enzymes, particularly for the conversion of lignocellulosic material from a variety of feedstock.

Synthetic biology and metabolic pathway engineering are examples of emerging technologies that will significantly increase the diversity of biotechnological processes and products, driving the development of innovative products. These techniques lead to the development of the so-called "microbial cell factories", which are production hosts that produce desirable products in high yields and with high productivity.

However, some of these bio refinery products will require further chemical processing and unless these chemical processes are made available there will be 110 markets for these precursors. Therefore dedicated research on the combination of technologies such as biochemical and chemical processes should also be given a special attention.

The OECD estimates that approximately 75 percent of the future economic contribution of biotechnology and significant environmental benefits are likely to come from applications derived from agricultural and industrial biotechnology. However, these sectors currently receive less than 20% of all research investments made by the private and public sectors. Therefore there is a pressing need to boost re search in agricultural and industrial biotechnologies by increasing public research investment, reducing regulatory burdens and by encouraging private -public partnerships.

It is also crucial to secure a sustainable supply of feedstock for the KBBE. This will require further research into methods of improving feedstock yields and/or the composition of biomass for optimal conversion efficiency. This research will involve both plant genomics and new breeding programmes, and also re search into efficient crop rotation, land management and land-use change issues.

Identification of Measures to Facilitate Access to Technology (SMEs) and Access to

Manufacturing in Europe (Policies for SMEs)

In order to better align academic knowledge to industry needs, industry will need to develop an earlier understanding of the application potential of new technologies provided by academia. Similarly, academic researchers will need a sharper focus on industry's needs and specifications.

Therefore, building competence networks between industry and academia could be key to overcoming the knowledge gap and competence hurdle that currently exists. In addition, better interdisciplinary and collaborative research would also lead to new business activities.

Moving forward, Europe needs to mobilise sufficient resources to support a Europe-wide coordinated research programme by means of a public' private partnerships. This would help build upon the successes of the European Technology Platforms (ETPs), FP7 and national research programmes. This type of joint undertaking would achieve a pooling of resources which would help in setting more ambitious goals in terms of reducing the time-to-market and which would also help industry to adopt long-term investment plans in the field of the bioeconomy, taking into account the market perspective. The main objectives of such projects are to share the risk of the development of innovative products and processes through support for research of a more "pre-competitive nature". This should cover the entire value chain, and should also encourage the uptake of research results by industry. Indeed, one of industry's major challenges is to translate research into products, including the development of new product applications. Such public private partnerships can also optimise knowledge transfer, and dissemination of knowledge towards SME's.

Identification of Potential Gaps in Terms of Resources and Infrastructure

(Assessment of Infrastructure Development Needs)

Since the bio economy will provide the solutions to some of societies most significant challenges, it should also be considered for increased levels of public funding. In addition, in order to make a swifter shift towards developing more integrated and sustainable production and processing systems, the level of R&D funding in the bio economy should be increased through multi disciplinary research programmes at national and European level.

Furthermore, improved coordination and collaboration between member state, regional and European public programmes for research and innovation is the only way to avoid overlap and fragmentation and to keep track of the massive research programmes in the US and in the BRIC countries. In addition, an operational framework should be established in order to facilitate the assembly of European, national, and regional funds to ensure European cooperation and competitiveness in this area. This should be done in conjunction with improvements in the cooperation between the private and public sectors.

Potential Demonstration and Market Replication Actions at EU Level to Facilitate

Deployment

It is important to foster the synergies between various participating sectors for example through the stimulation of public-private partnerships. This cooperation must extend downstream to demonstration projects that facilitate the development of flexible, research - oriented pilot plants to validate the concept of integrated and diversified bio-refineries. Pilot infrastructures to demonstrate the technologies and to test new feed-stocks and pre-treatment processes already exist to some ex tent but the se need to be complemented by larger scale demonstrators to verify scale-up of processes. The initial construction of bio-refinery pilot and demonstration plants is not only a costly undertaking but it also involves bringing together market actors along a new and highly complex value chain. This ranges fro III the diverse suppliers of biomass raw materials (farmers, forest owners, wood and paper producers, biological waste suppliers, producers of macro· and micro algae etc.) with industries providing the technologies and industrial plants to convert the raw materials and the various end users of intermediate or final products.

Countries like the US, Brazil, China and others are increasing investment into research, technology development and innovation, and are supporting large scale demonstrators in which many European companies already participate.

Results from KET Working Group Advanced Materials

The group concluded with the following thoughts:

1) as mentioned in section I advanced materials technologies can contribute to addressing raw materials availability issues by 3 types of actions:

o long term: develop substitution materials

o medium term: design-for-recycling

o short term : improve access, enhance recycling and develop recycling technologies

A preliminary initiative towards design-for-recycling could already be taken during the 2nd part of the KET -time period: if deemed beneficial contact can be established with the Raw Materials Supply Group to investigate how best to tackle this.

2) technology co-development and industrial collaboration across intra-value chain boundaries needs to be stimulated between the advanced materials and device segments including relevant equipment suppliers, preparing for linkage with downstream segments attracted to Europe by means of market pull policies or once application markets mature. This position was also evoked by several Open Day speakers, a quote from the talk of Bruno Smets speaking for Photonics 21 as an example: .. verticaly integrated initiatives are needed, ... , incremental progress over a substantial part of the value chain is worth more than an isolated breakthrough for I material". For such policy to be successful attention needs to be paid to following elements:

- co-development initiatives should build on and expand remaining European advanced materials leadership positions ; examples for silicon-PV, CPV and battery materials can be provided, other industries will certainly be able to provide other opportunities

- incorporate a strong focus on operational excellence in these co-development initiatives, as Europe is losing / has lost its strong position in this domain; this may be one of the most difficult challenges as it requires a change in attitude or even culture at all company levels

- help selected strategic co-development initiatives to cross the "pilot-plant gap" ; as emphasised by several speakers at the Open Day many interesting technological developments don't make it past R&D because the risk is still too high for private funding of demonstrators / pilot plants with a price tag of > 10 MEuro. EU assistance for high-potential projects, for example by means of risk-sharing EIB loans (repay in case of success only), could remedy this problem.

- technology development infrastructures combining different but similar advanced materials and device technologies can be instrumental in achieving co-development success (intermediate step between universities and company in house) ; an example of how such infrastructure could look like (nano extrem-fab) was presented during the October 25th Advanced Materials Open Day.

3) in support of the first industrialisation stage of selected strategic projects, lax advantages similar 10 those currently available in the new member states could convince the industry to invest in Europe. The gap with for example Singapore and other Asian countries would not be eliminated by these policies, but it would be an important step.

Results from KET Working Group Micro/Nanoelectronics

These recommendations were derived during the Micro/Nano Electronics Open Day event in 2010 in Brussels, organised by the working group:

A) Clusters, R&D and Proto-typing:

- Support the development of leading-edge clusters, and the cooperation between them.
- Leverage these leading-clusters through supporting cooperation between the clusters and global European Industry (possible specific calls in FP8).
- Develop European instruments to promote and stimulate European cross-border (and cross-cluster) collaboration.
- Ensure early prototyping capabilities, especially for devices and applications based on "More than Moore" technologies. Suggestion was to fund 5 to 10 EU "LabFabs", based

on existing centres of excellence, where sm311 system technologies are developed and 5mal1 systems are prototyped, manufactured and brought to market in a short loop. This network of"LabFabs" could constitute the key European Infrastructure for heterogeneous integration, where System OEM, Semiconductors, Research labs, SME's, will cooperate to define and produced the best in class sm311 systems;

- Promote the access of SMEs to leading edge technologies, through specific funding support
- Strengthen 300mm positions: develop a strategy and a large program for granting longtenn production in Europe of advanced nano-electronic chips (processors, ASICs, Systemon-chip (SoC)) and strategic equipments/material (lithography, epitaxy, smart substrates), by leveraging the strengths of existing clusters;

- Support the link between European designers and technology clusters, in order to accelerate the rate of application of those technologies into products for the benefit of industry globally through Europe. Consider specific calls; consider a premium for usage of Europe-based manufacturing, in funded programs;
- For "More than Moore", develop and secure the key technologies: power devices, sensors.
- Explore 450mm: cU1Tently limited to equipment/material European suppliers needs, unless a serious perspective and commitment is made by the EU to 450mm manufacturing in Europe.

B) Manufacturing

All participants at the Open Day acknowledged the strategic importance of keeping manufacturing capabilities in Europe for some key areas, due to the wealth creation, and to the leverage effect on other sectors. Other areas (Asia, US) have endorsed that strategic interest in their strategy, and strongly support manufacturing as well as R&D.

A generic recommendation is to consider and promote actions that enhance competitive advantage for Europe. Most recommendations are developed in 'Regulations' sector.

Recommendations from the E-MRS/MATSEEC Report

In this report, a detailed analysis of the five KETs and their role in solving the main challenges is presented by starting with an analysis of the present situation and then following up with suggestions and an outlook for the future. Below, a number of key recommendations is summarized:

- In some areas of **micro- and nanoelectronics** (MNE) Europe is still leading. Among those are power electronics, high frequency devices, and micro and nano-electromechanical systems (MEMS and NEMS). In order to keep and strengthen this position it is of utmost importance that a proper **wafer production is available in Europe**. All possible efforts must be made to take part in the upcoming transition to a technology based on 450 mm wafers and not to restrict future activities to centres and companies performing design and simulation only.

- Europe is leading in **computational materials science** worldwide. State-of-the art multi-scale modelling of the relation microstructure - properties is needed both for the understanding as well as the design of different types of advanced materials. Modern predictive materials modelling will be of key importance for European industry and in this respect the technology transfer to industry needs to be vigorously pursued.

- In the field of **advanced materials** it will be necessary to strengthen approaches to the rational design of advanced materials and their integration into structures and systems It is therefore imperative to further support the expertise gained in hybrid materials, to integrate concepts of green chemistry and biotechnology in materials design and production, and to anticipate and control better the performance of materials during their entire life cycle.

- Due to promising applications in the field of **nanotechnology** it is mandatory to further develop this technology in areas such as energy, nano-bio applications, healthcare, security, etc in Europe.

- In order to exploit fully the breakthroughs offered by nanotechnology a **European open access centre for nanofabrication** should be created offering state of the art materials processing and characterisation facilities with strong links to industry.

- Carbon dioxide can be used as a raw material for electrical grid regulation and for the development of a new industry based on its recycling. In order to do this close cooperation between research centres and industries on this issue should be facilitated.

The whole report also underlines the necessity to strengthen **innovation** in Europe by **creating innovation incubation centres** in the form of private-public infrastructures with participation of universities, research centres and industries in several well chosen strategic fields.

How to obtain EU publications

Free publications:

- via EU Bookshop (http://bookshop.europa.eu);
- at the European Commission's representations or delegations. You can obtain their contact details on the Internet (http://ec.europa.eu) or by sending a fax to +352 2929-42758.

Priced publications:

- via EU Bookshop (http://bookshop.europa.eu);

Priced subscriptions (e.g. annual series of the Official Journal of the European Union and reports of cases before the Court of Justice of the European Union):

- via one of the sales agents of the Publications Office of the European Union (http://publications.europa.eu/others/agents/index_en.htm).