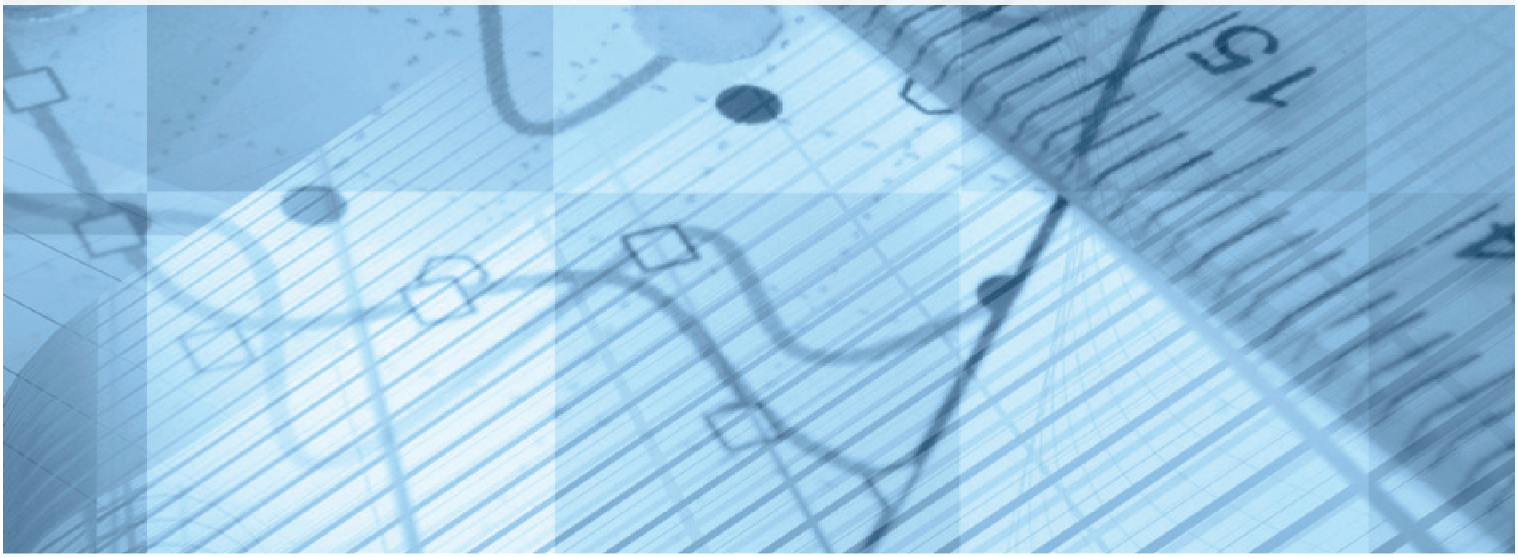
Materials Science and Engineering Expert Committee (MatSEEC)

Knowledge and Technology Transfer in Materials Science and Engineering in Europe

Working Group Report



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Materials Science and Engineering Expert Committee (MatSEEC)

MatSEEC is an independent science-based committee of over 20 experts active in materials science and its applications, materials engineering and technologies and related fields of science and research management. Committee members are nominated by their member institutions and they maintain strong links with their nominating organisations and their respective scientific communities.
The aim of MatSEEC is to enhance the visibility and value of materials science and engineering in Europe, to help define new strategic goals, and evaluate options and perspectives covering all aspects of the field.

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Executive Summary

Advanced Materials is one of the Key Enabling Technologies identified by the European Commission[1]. Together with Advanced Manufacturing it underpins almost all other Key Enabling and Industrial Technologies. The basic science and engineering research that results in the development of Advanced Materials lies within the field of Materials Science and Engineering (MSE). The transfer of knowledge from basic research into final products and applications in the field of MSE involves certain MSE-typical motifs and specific issues, as well as certain aspects that are special to Europe. In comparison with underlying traditional (or basic) disciplines such as physics, chemistry or biology, MSE involves a range of aspects that are more characteristic of applied science, where relevance has equal importance to curiosity in order to drive the research effort and justify expenditure – the defined goals often being a proven innovative technology or indeed a particular product. MSE and the related transfer of knowledge and technology includes consideration of factors such as materials and product life cycles, the abundance of materials, the technical, ecological and economic feasibility of materials engineering and processing, as well as the multidisciplinarity of the 'background' knowledge and the efficiency of the academic effort involved. This is even more the case for situations that involve successful validation of technologies and effective transfer of knowledge between academia and industry. The state of knowledge and technology transfer in Europe differs from that of other global players, such as the US, China or Japan. Europe's cultural diversity gives rise to both positive and negative factors. Positive aspects include the high standard of general education and Europe's highly skilled work force (for both technical and academic staff), and the flexibility and variety of research topics and directions. Major negative factors are the fragmentation of national research efforts, and the lack of a European mechanism to create critical mass in new technologies and to invest in pilot lines. These negative issues are manifested by the fragmentation of research programmes, the lack of venture capital and a general risk aversion on the part of investors in Europe, in particular in the light of the current economic crisis in Europe. The present situation has often been described as a malfunctioning interface between strong basic research and poor, inefficient technological development and commercial exploitation of knowledge. MSE spans this interface. 'European' knowledge is world-class, and even leads the world in certain fundamental areas of MSE, for example in the investigation and understanding of materials properties, the development and application of new concepts of materials design, computational materials sciences, and several other fields. However, Europe's MSE knowledge and technological progress will not readily lead to the establishment of new technologies and products by European industries without dedicated intervention. This knowledge must be delicately directed in a highly impact-oriented way. To accelerate development and validation of technological applications and the introduction of technological innovation into the market, to intensify the collaboration between academic institutions and industry in Europe, and to facilitate the creation of spin-out companies and new industrial–academic career paths, MatSEEC recommends the creation of European Technology Research and Validation

1 http://ec.europa.eu/enterprise/sectors/ict/key_technologies/kets_high_level_group_en.htm

Platforms (ETVPs). Such platforms would provide powerful tools for innovation and allow better protection of intellectual property rights in Europe. We recommend the creation of an 'Open-Access-Open-Innovation' European Technology Research and Validation Infrastructure Initiative to streamline and improve technology and knowledge transfer in Europe. The initiative would be dedicated to technology research and validation. It could be based on a similar model to the current Integrated Infrastructure Initiatives (I3s) for research infrastructures of the European Commission (the I3 Programme in H2020 and the Seventh Framework Programme, FP7).

1.
Introduction

Historically, Materials Science and Engineering (MSE) emerged as an interdisciplinary field with its roots in several traditional disciplines, such as physics, chemistry, biology, mathematics and mechanical engineering. MSE integrates concepts or methods that may have been originally developed by these disciplines, and applies them to the design of new materials, materials systems and, ultimately, new products. MSE-based research and development seeks new concepts and methods to characterise and tailor materials properties, and to provide engineering solutions for the most appropriate materials systems to meet predefined specifications. This includes identifying the most appropriate processes for fabrication and life cycle management taking the necessary economic and ecological considerations into account. Thus, MSE has evolved over the last half century into a truly transdisciplinary field in its own right, crossing the boundaries of root disciplines to describe, model and engineer new materials properties for target applications and new products.

MSE is fundamental for several technologies. It addresses all stages of the innovation chain from fundamental research to advanced engineering applications, better production technologies and new products. The results of MSE research and development are found in all stages of the value chain from raw materials, via products and engineering systems, to technology validation; from new services to new solutions that meet the challenges that face today's society. MSE continuously improves the competitiveness of both conventional industries and novel technology sectors. MSE innovation is the 'raison d'être' for many small-, medium- and large-scale industries.

MSE is central to all societal needs as categorised by themes such as energy, health and wellbeing, environment, information and transport. The societal impact of MSE is, therefore, hugely significant and depends on the effective interconnection of three key aspects:

- *Knowledge generation* – through basic and applied research, academic education and later career training;
- *Knowledge transfer* within academia and from academia into commercial and industrial sectors, but more importantly here the transfer from industry into academia, something that is currently chronically neglected in academia;
- *Development of new technologies* to produce new products and services.

The intention of this report is firstly to assess the status of technology and knowledge transfer in the domain of MSE in Europe, from the incubation of new ideas generated from within academia to the implementation of final products in the market. Secondly, the report aims to reflect MSE experts' opinions on this issue and to make specific recommendations to European policy- and decision-makers on how to improve knowledge-transfer mechanisms within Europe.

2.
Materials Science and Engineering in Europe

2.1 MSE in relation to Europe's competitiveness

A significant part of the global economy is based on the development and provision of new products and services in better, cheaper or faster ways. The ultimate goal is to provide solutions to the great societal challenges faced by Europe and the rest of the world. Materials underpin innovation and can yield a sustainable advantage in a competitive global economy. Europe has been the cradle for new technologies since the invention of the steam engine and the birth of the industrial revolution, and Europe's future will depend on how it will manage and develop today's new technologies, such as nanotechnology, biotechnology, nanoelectronics, advanced materials and photonics[2]. In particular, in order to champion the transition to a low-carbon, knowledge-based economy, Europe will need to restructure a large set of industrial processes, modernise its industry and strengthen the research–development–innovation chain with a strong focus on its own territory. This ambition will not be achieved without new materials design and new materials processing.

Both the most advanced and the most traditional industrial sectors need distinct materials-based innovation that will only emerge from new discoveries in the field of MSE. According to recent analysis, the share of high-tech industries in Europe in manufacturing added value amounted in 2002 to 16%, compared with 23.3% in US.[3] Clearly, Europe needs to increase its share of advanced production technologies while strengthening its competitiveness in other more traditional fields of industrial activity (for example plastics, ceramics, textiles, and so forth). This will require a continuous and mutual two-way exchange between industry and academia.

To assess opportunities and threats pertaining to activities in materials and materials engineering in Europe one must understand the relationship between knowledge at one end of the process and the development of an industrial product at the other. A useful way to rationalise this connection is by involving the concept of innovation and value chains.

The ***innovation chain*** is the chain going from (a) basic research, to (b) applied research, to (c) demonstrator projects and prototyping, to (d) early stage commercialisation and, finally to (e) mass production.

Europe is traditionally strong at the early stages [left-hand side, (a) to (c)] of the innovation chain, but falls behind North America and East Asia when it comes to the commercialisation of research-based products and subsequent mass production [right-hand side, (d) to (e) of the chain].[4] This has been termed the 'European Paradox'[5], a situation which hampers the transformation and competitiveness of European industry. To overcome this problem, action is required to give a new thrust to European competitiveness and to effectively move through the following scheme:

1. Foster the transformation of scientific results into a new technology.

2 High Level Group on Key Enabling Technologies – Final Report, June 2011, http://ec.europa.eu/enterprise/sectors/ict/files/kets/hlg_report_final_en.pdf and subsection on photonics

3 Report on European Technology Platforms and Joint Technology Initiatives: Fostering Public–Private R&D Partnerships to Boost Europe's Industrial Competitiveness, 2005

4 See *European Competitiveness Report 2010*, European Commission

5 European Commission in its Green Paper on Innovation, 1995, http://europa.eu/documents/comm/green_papers/pdf/com95_688_en.pdf

Table 1. Value chain for advanced batteries

Raw materials	Equipment	Devices	Product	Services	Solution for society
Electrode materials, nanopowders	Assembly line, packaging	Battery cells, power management	High performance battery	Electric vehicles	Sustainable and green mobility

2. Provide proof-of-concept for the new technology by prototyping.
3. Ramp up prototyping into large-scale production.

MSE addresses issues that are at the core of each of these steps. Progress can only be made if academic and industrial partners act closely together during the first two stages: transforming science into technology and facilitating demonstrator and production-driven projects.

On the other hand, an optimised ***value chain*** implies favouring the transition from (a) raw or semi-processed materials, using (b) adequate equipment, into (c) devices, into (d) products and (e) services, and finally into (f) solutions to societal challenges. An example is shown in the table below that describes the value chain for advanced batteries.

Clearly MSE provides crucial inputs at all stages of this chain. It is important to keep in mind that more than just well-protected patent and intellectual property rights are needed to secure a technology-based manufacturing chain. Industrial product standards and norms must also be set and controlled in order to secure an entire value chain (that is, at all stages/links). To create a sustainable and strong industrial manufacturing sector, Europe must have a stake in and be a champion for a new technology in its entirety, in other words along the full value chain. Precisely who covers a value chain in its completeness will effectively define the standards and norms.

Europe is traditionally weak on the raw materials side and must enhance its efforts in developing new substitution materials, as well as in setting an efficient raw materials management policy (in terms of both availability and recycling). Therefore, Europe has to dedicate additional efforts to MSE.

2.2 Characteristics of MSE-based technologies and the European situation

MSE-based technologies are fundamentally:

- Knowledge intensive: they require a highly skilled interdisciplinary workforce and a strong commitment to high-level research and development activities.
- Capital investment intensive: new testing and production facilities require initial investment.
- Disruptive or transformative: they are subject to rapid and integrated innovation cycles; they can quickly make other technologies obsolete and they themselves can be rapidly superseded by other materials-based technologies.

Regarding the first point above, the EU remains in a fairly strong position in relation to other global regions. The EU still has a highly trained workforce and excellent research facilities. Universities and research centres such as CNRS, Max Planck, CSIC, Fraunhofer, CNRI, and many others, should maintain their competitiveness in fundamental research to design, synthesise and process new phases and novel atomic architectures to serve as an upstream reservoir for future families of 'materials for…'. Nonetheless, Europe's position has come under serious threat in the last decade as the numbers of science, mathematics and engineering students has decreased significantly[6]. Increasing the number of highly trained engineers is a critical societal challenge for Europe's secondary educators, universities and research organisations. Mobility of researchers and engineers is another crucial issue which requires new policies and organisational measures. Ideally, the specific measures aimed at facilitating the mobility of individuals working in science and technology should be complemented by institutional cooperation between universities, non-academic research and technology organisations and technology companies. Facilitating cross-border funding and investment by the different stakeholders within Europe is a clear path that

6 For example, the number of students in the fields of science, mathematics and computer sciences has fallen from 12% to below 9% since the year 2000. http://www.ehea.info/Uploads/(1)/Bologna%20Process%20Implementation%20Report.pdf

needs to be taken to start reducing the European technology gap.

Concerning the second bullet point above, here Europe is traditionally weak. There is a lack of sufficient financial investment and a willingness to spin out technologies or install demonstrator production lines. Venture Capital (VC) is scarce in Europe, particularly in comparison to North America and East Asia.[7] Reasons for this situation are related to the fragmented European landscape in which national VC funds do not readily cross borders. Another effect of this fragmentation is the lower return on investment when innovation is introduced in several 'smaller' countries – each with its own patent rules, financial systems and tax schemes. These and other factors mean that even European investors tend to support initial market production in large single markets such as the US, rather than to invest simultaneously in various European countries.

Above all the lack of finance for large production facilities for new products is the most pressing bottleneck in Europe. Large-scale pan-European funders are rare. National borders and state-aid regulations tend to hinder EU-wide financial schemes for local production facilities. Another negative issue, which may be related to the previous one, is a weaker entrepreneurial mindset among European scientists and engineers. Several European universities offer entrepreneurship education, but more and original initiatives have to be promoted to provide dedicated entrepreneurship training for engineers and scientists.[8] European-wide financial risk aversion is another issue which has worsened during the current financial crisis. There needs to be a level playing field within the EU, allowing greater flexibility in funding schemes. This would require EU regulations to be altered to allow for multi-state funded yet single-sited, large-scale production facilities with critical mass.

Concerning the third bullet point above, the most important demand is speed. Too often, fund-

7 Henning Kroll, Andrea Zenker, Torben Schubert.' An analysis of the development of R&D expenditure at regional level in the light of the 3% target', Directorate General for Research, 2009

8 See for instance: http://ec.europa.eu/enterprise/policies/sme/promoting-entrepreneurship/education-training-entrepreneurship/index_en.htm or https://www.nae.edu/File.aspx?id=88638, Tom Bryers, Tina Seelig, Sheri Sheppard, Phil Weilerstein, 'Entrepreneurship: its role in engineering education'

ing programmes or initiatives in Europe have longer timelines than in North America and East Asia, or they are under-resourced.[9] A clear example of this issue is the lack of administrative simplicity in EU research projects. On the other hand, financial risk aversion leads to delays in implementing new technologies and the time-to-market is often extended by the lack of easy access to loans and financial guarantees. This is critical for advanced materials demonstrator projects which usually require quick decisions to speed up their implementation to ensure that the resulting innovative products may be brought to the market in time, a decisive requirement if there is to be optimal return on investment.

Generally, Europe is too slow in exploiting its patents and the application of its research. One reason for this, which also contributes to slow response times and hinders implementation in Europe of effective responses in relation to the last two bullet points above, is the lack of a simplified European patent application process. The underlying political discussion is complex and beyond the scope of the present report. Nonetheless, we must emphasise the need for a simple and common scheme of patent applications in all EU countries written in one (English) or two languages. A simplified framework is considered a crucial 'must-have' to accelerate effective transfer of knowledge from academia to industry at the European scale.

9 http://books.google.fr/books/about/Academic_Entrepreneurship_in_Europe.html?id=tRo9SnOjl_MC&redir_esc=y

3. Measures for strengthening technology and knowledge transfer in MSE

As described in the previous section, MSE underpins almost all new technologies. The impact of materials and materials processing/engineering at any stage of the value chain is generally positive, provided that the three following major aspects are equally addressed: knowledge production, knowledge transfer and the development of technologies.

Measures to strengthen technology and knowledge transfer are particularly important in the light of the European Paradox in the innovation chain. Knowledge production is excellent in Europe and its quality and quantity should be maintained or even enhanced. Even the development of new technologies up to the proof-of-concept stage is more advanced than in the US or Asia. However, a clear weakness appears in the latter phases, when prototyping and initial-stage manufacturing require dedicated financing and private investment. Venture capital appears to arrive slowly and at lower levels in Europe. The response, so far, has been to encourage public–private partnerships, which is an excellent concept but such partnerships tend to develop more slowly in the EU than in competing economies. Here, more analysis and careful diagnosis would be helpful to create new and innovative business models in Europe.

The European Paradox is particularly evident further downstream, at the later stages (after proof-of-concept) of what is often called the 'valley of death' in the innovation chain or the 'market evolution of start-ups'. The lack of sufficient public–private funds for prototyping – after technology validation has demonstrated the innovative potential – is a clear example of the existing shortcomings for converting scientific results into products.[10] This gap is an intrinsic feature of a market economy: it is the demarcation line between public funding (through the taxpayer) of research projects and private investment, which follows market rules and demands a return. In general, this is a global phenomenon. The width of the valley and the severity of the problem is, however, peculiarly European. The valley is wider than in any other industrialised economy in the world. The particular problem is that proof-of-concept, demonstration and validation are achieved faster in Europe, but once the technologies are established, manufacturing facilities are established more quickly in regions outside of Europe, which are then in the position of being able to sell the innovative product back to Europe. MP3 players, flat displays, Li-ion batteries and solar panels are just a few recent examples of technologies first developed and even patented in Europe that led to innovative products being manufactured elsewhere. This is generally visible in the mismatch between the number of European patents licensed inside Europe but exploited outside Europe. To negotiate the valley and to become more competitive, Europe needs its own tailored funding models for pilot lines and prototype production facilities. The so-called 'knowledge society' is necessary for but not alone sufficient to sustain a modern economy. Knowledge must be exploited through innovative manufacturing facilities. New materials, new processes and life cycles underpin manufacturing innovation. Knowledge creation in MSE must be strengthened and complemented with new business

10 Report on European Technology Platforms and Joint Technology Initiatives: Fostering Public–Private R&D Partnerships to Boost Europe's Industrial Competitiveness, Commission of the European Communities, 2005

strategies and funding schemes for prototyping and large-scale production before the technologies are licensed/sold outside Europe for commercialisation.

Only a few general considerations of the European Paradox and Europe's weaknesses have been sketched here. Several scientific and economic trends have an impact on the Europe's weakness at utilising its strong academic base in MSE to market new products, and the complexity of the situation will require bold political decisions if an effective solution is to be found. Political action must aim to facilitate and support the creation of new technology products in the commercial market while further strengthening Europe's scientific excellence in MSE. This report intends to highlight some of the key strategic concerns and to provide concrete advice on implementation measures from the perspective of MSE activities in Europe. In the following sections, specific European problems are identified and actions proposed. This analysis is carried out with a focus on academic–industrial collaboration, access to information, access to funding, creation of spin-outs and professional careers. This is followed by some considerations on intellectual property rights (IPR) and regulations for MSE in Europe. The final section presents a summary for action through the proposal for an Integrated European Technology Research Infrastructure Programme for Materials Science and Engineering in Europe.

3.1 Academic institutions and industrial collaboration

Certain **requirements** for successful collaboration between academia and industry, that is to say the commercial sector, can be readily arrived at in the light of the information presented in the earlier sections of this report.

- Materials Science and Materials Engineering are knowledge-intensive disciplines. Europe has a large and highly sophisticated research community and must continue to enhance its knowledge base and its advantages in *knowledge-intensive* materials. To accomplish this in a more efficient way, Europe must improve its intellectual property protection and strengthen the links between academia and industry.[11] Joint academic and industrial careers must be made more viable and routine. Universities must create more high level teaching positions for chief technologists from industry. Social security systems and pension plans must become transferable across Europe, not only for researchers at different universities or laboratories but also for engineers and technicians across the academic–industrial interface. Career mobility between industry and academia must be increased in both directions. For instance, this can be initiated through Europe's research and technology organisations and technical universities, or universities of technology and applied research.
- Speed matters: The 'first mover´s advantage' is time. Research results and application testing must be moved to the market quickly. This need has to be reconciled with the protection of IPR that results from publicly funded research. In this regard, it is worth noting that, particularly in Europe,[12] small- and medium-sized enterprises (SMEs) have a critical role to play in speeding up the transfer of research applications to the market. This implies that collaboration between academia and these growth companies should take place in a favourable framework.
- Money matters: Flexible financial schemes with significant volume must be available to allow the transition from creative ideas and initial testing to demonstrator projects. These demonstrator projects must address the needs or requirements of the commercial sector concerning competitiveness and profitability of any new technology or product.

To help meet these requirements, a series of **recommendations** should be implemented within the European R&D system, particularly in the field of MSE.

Specialisation of research centres/departments working in the field of MSE

Integration of multidisciplinary skills and competences will be one of the key factors to ensure knowledge generation in materials science, producing success stories stemming from MSE research activities. Therefore, critical mass (both in terms of personnel and resources) in MSE-oriented research centres and universities is extremely important to ensure a strong and complete value chain. This implies specialisation of the research centres/departments in particular areas, while at the same time ensuring coverage of the whole value chain in that specific theme, from the fundamental to more commercial issues. In other words, it is important to avoid 'horizontally' organised institutes that pursue various parallel research lines in different topics and thereby deliver fragmented coverage across diverse

11 A. Piccaluga, Ch. Balderi, A. Patrono, The Proton Europe Seventh Annual Survey Report (fiscal year 2009)

12 Key Figures on European business with a special feature on SMEs, Eurostat Pocketbook, 2011 edition

fields. For example, an institute on 'Photo-active Polymers' would be preferable to a new centre for 'Materials Science' or 'Nanotechnology', that has a broad portfolio of research topics to address. Another example would be a research centre focusing on a linear chain of research and development activities spanning synthetic chemistry to the production of organic solar cells, covering the whole value chain.

Restructuring the activities of transfer units in universities and other EU public research organisations

A common working scheme of recently established technology transfer units in universities and research organisations in Europe has been to create a centralised office dealing with administrative and legal issues. Notwithstanding the importance of these functions, for efficient transfer of knowledge in MSE it is recommended that highly centralised transfer offices be avoided. Such offices can become too detached from research laboratories and actual technology-based business models. A closer, more direct involvement with researchers requires a specific understanding of the particular technologies being developed in the laboratories. Technology push – or fundamental research push – alone has failed to create sustainable technology transfer. Market-pull – or relevance and impact potential – may be even more important. This must therefore feature in the particular technology transfer model. A profound understanding of the industrial bottlenecks – the relevant challenges that companies need to solve – is equally essential. Universities and researchers must become able to identify the relevance and impact of technologies and innovation to which they can direct their curiosity-driven effort. New materials, new processes for materials, more economic production and recycling, and substitute materials are the major themes that require improvement. To innovate here calls for more interaction with industry and the ability to pursue joint careers, where technology developers can move more freely and faster between academia and enterprise. More universities need to create dedicated entrepreneurship training curricula for scientists and engineers.

New and flexible public–private partnerships for MSE

Europe needs to introduce new measures to reinforce technological research and to shorten the time it takes to bring the new technologies to the market. Involvement of the industrial sector is vital. SMEs have limited resources and highly focused business plans, so while SMEs may have the capacity to participate in development and innovation activities related to their existing production lines, they rarely have the capacity to embark on uncertain R&D activities on potentially disruptive processes/products.[13] This carries the risk that some breakthroughs from research laboratories may not find timely implementation in the market through the involvement of European companies. To facilitate industry's participation in high-risk research that has medium-term application potential, new and flexible public–private partnership (PPP) initiatives need to be explored and tested in MSE. These new PPP experiments should include SMEs, industrial consortia, academia, Research and Technology Organisations (RTOs) and governmental research organisations. Whilst they should minimise the risk to SMEs for participation, these PPPs should target medium- to long-term technology validation even where a practical return on investment in the form of new products is not predictable.

Use Europe´s Research and Technology Organisations (RTOs) as model public–private partnerships to link academia and industry when curiosity-driven research has technological significance

The transfer of research results into new applications and the development of new validated technologies is the explicit goal of Europe's RTOs, such as TNO in the Netherlands, VTT in Finland, Tecnalia in Spain, CEA Technologies in France or Fraunhofer Gesellschaft in Germany. These RTOs have strong links with academia and have the specific mission to create technology-based innovation (highlighted in Section 2.2). These organisations have long and impressive track records in publicly funded precompetitive research and dedicated contract research for industrial customers. Most RTOs (the largest ones) are not-for-profit organisations, dually funded through private contracts and public funds. They are also well-experienced in implementing the necessary legal separation between public and private investment. They also have established tried-and-tested models to protect the IPR rights of European taxpayers, as they develop new technologies and provide sustainable services to technology companies, i.e. manufacturers. Particularly in the field of MSE, Europe's RTOs offer strong and transparent services to help to cross the innovation gap (the valley of death) in Europe. Currently, there are several initiatives in East Asia and North America that seek to imitate these uniquely European organisations. For instance, the US Government's National Network of Manufacturing Institutes Initiative (NNMI). [14,15]

However, one must remember that RTOs bridge basic research and commercial enterprise. They do not substitute for either basic research or commercial exploitation. RTOs need both sides of the bridge as partners. Nor do RTOs operate in all European or EU countries. Here, universities and basic research institutions may assume substantial bridging roles. Therefore, it is recommended that research departments and institutes in universities and other research centres interact and collaborate across European borders with existing RTOs to integrate best practices for technology innovation in their own systems, and also exploit the tested validation mechanisms of RTOs for their own benefit. Clearly, the implementation of such organisational schemes must not alter or divert the mission of the university or research institution, which first and foremost must maintain the highest level of basic research. Collaboration with RTOs represents a way to achieve added value added towards promoting more efficient transfer knowledge to industry. An encouraging step in this direction is the high percentage of RTOs that are partners in the EU 'Twinning' and 'Teaming' Programmes in Horizon 2020.[16]

Encourage stable alliances between different actors (industry, RTOs and universities) to co-develop technologies

MSE is one of the most prominent and obvious fields for active collaboration between European RTOs, universities and other research organisations. The engagement of these organisations in alliances to share access to their different facilities and technological infrastructures and co-develop technologies on a European scale is a clear necessity for the future. Such alliances would be ideally positioned to generate European platforms for technological development, while continuing to abide by national regulations in their respective countries. Such collaboration would produce a strong link between industry and academic training and basic research. Another virtue of such alliances would be to ease the transfer of fundamental knowledge to industry. As noted earlier, a certain proportion of European industry, particularly SMEs with their structure and dimensions, is not always keen to collaborate in the implementation of MSE-related disruptive and inno-

13 See for instance, http://londoneconomics.co.uk/blog/publication/partial-fragile-recovery-annual-report-european-smes-201314/ and further references there, or on updated sites from the European Commission

14 'Innovation: a preliminary design', http://www.manufacturing.gov/docs/nnmi_prelim_design.pdf

15 'Opportunity for All: Investing in American Innovation'. The president's budget. Fiscal year 2015

16 See http://ec.europa.eu/programmes/horizon2020/en/h2020-section/spreading-excellence-and-widening-participation and updated references there

vative technologies that derive from basic research outputs of universities and research centres. It is expected that the type of alliance described, encompassing fundamental research, applied research and innovation activities, would serve as an ideal platform to transform fundamental knowledge into advanced final products.

3.2 Two-way information, the push-and-pull of transferable knowledge

An often neglected requirement for successful transfer of knowledge and technology in the field of MSE is good knowledge and understanding by scientists of the needs and bottlenecks in industrial processing and production. There needs to be a two-way flow of information. New scientific results from academia must be communicated to industry, and knowledge of engineering achievements and technical constraints within industry need to be communicated to academia. However, academics' awareness of and interest in the relevant issues in production and processing is suboptimal. It is deemed extremely important to strengthen dialogue at all levels among materials scientists, materials engineers and materials technology providers. Such fluid communication will be indispensable in addressing the new challenges arising from the interdisciplinary nature of MSE. Exchange of information between experts with different backgrounds and across the entire innovation chain is crucial. To strengthen communication between academia and industrial companies, we strongly **recommend** the adoption of the following **specific measures**:

1. *High level training courses* – Training and updating courses and forums for technicians and engineers should be promoted by universities and research centres to facilitate contact with scientists and create a common language. Good examples of this already exist, for instance the training courses of the German Metals Society, DGM.
2. *Format of Scientific Conferences* – Modifying and adapting the format of scientific conferences and congresses to enable the more active participation of industry is another good practice that would encourage stronger links between scientists and engineers. This is partially done in Europe already but needs more support. Closer industrial participation would help to better describe the challenges and needs of industry in specific aspects of MSE, as well as contribute to the dissemination of recent scientific achievements.
3. *Promote the participation of scientists in industrial conferences and forums* – The participation of scientists in industrial forums relating to specific activity sectors would also be highly advantageous for the mutual dissemination of knowledge and the assessment of the respective points of view with regard to specific aspects of MSE.

While the precise format of initiatives 2) and 3) above would need to be agreed upon and probably adapted to each sector of activity/knowledge in MSE, it is clear that strengthening the links between industrial associations and research organisations is an indispensable pre-requisite to bringing basic research results from MSE to the market more rapidly.

4. *Create a European database* – A centralised European database of technological advances/requirements that is accessible to academia and industry would be an intriguing initiative at the EU level as a vehicle to co-create more innovation between academia and industry.

3.3 Funding and new criteria

Funding is the critical bottleneck for any research and development activity. This is especially the case for what is widely termed basic or fundamental research, which these days is funded almost exclusively by the taxpayer. If funding comes from the public purse, this not only requires that the allocated resources are used in the most efficient way, but also that the public must be guaranteed a stake in any knowledge that is created. As a project that is both publicly and privately funded approaches the market, the more important the character of the public–private partnership (PPP) becomes. A PPP must enable the commercial buy-in or acquisition of a stake, while at the same time balancing the benefits or return-on-investment for both public and private partners. This is a particular characteristic of R&D in MSE and distinguishes MSE as a multidisciplinary yet *independent research field in its own right*. Funding mechanisms must take this independent character of MSE into account and offer dedicated programmes outside traditional modes of research in, for example, condensed matter physics, biology, chemistry or computational sciences. In particular, a *final product approach,* combining programmes tailored to individual phases of the innovation process, will ensure a more efficient transfer of knowledge in MSE.

Scientific and technological goal of MSE projects

MSE is an interdisciplinary area of knowledge which uses concepts and methodologies from a wide variety of disciplines, such as solid state chemistry and physics, biology, structural engineering, environment and recycling, among many others. MSE R&D requires broad and unique skill sets across those disciplines, which makes MSE unique. As noted in Section 2.1, the development of final applications and the fabrication of prototype materials and devices is a much stronger and visible element or ingredient of MSE projects than for many other areas of science or engineering. Conventional research in disciplines such as physics, chemistry or biology tends to focus on the study and characterisation of certain properties or 'natural effects'. MSE projects, on the other hand, typically go beyond mere characterisation and aim to tailor properties and technologies to create process innovation and new advanced materials. 'Final product' approaches must therefore be specifically borne in mind when contemplating funding schemes for MSE.

Involvement of industrial partners

Partnerships with industry are encouraged on condition that the companies become actively involved, provide significant input and are willing to commit resources for the project. Active involvement can take place at different levels. However, at the very least the industrial partners should provide specifications and requirements for the materials and final products to be developed. Where possible, and without limiting the scientific and technological quality and excellence of the projects, industries should be involved with the upstream part of the value chain, and address issues such as product development, commercialisation, up-scaling for mass production, and so forth. The best results are usually achieved when the project goals are set jointly between industry and the research partners.

Project objectives in MSE

In any research project, the amount and type of funding is tightly related to the project's objectives. To improve the transfer of knowledge, materials processing and final product development must be benchmarked deliverables of the proposal. To monitor and control the various tasks and deliverables of a project, funding should contemplate the milestones and deliverables at the end of the value chain when considering the level and distribution of resources. This is to allow more flexible allocation of resources and to cover the expenses for all research and development phases, from fundamental research to applications, considering their importance for the outcome of each project. A good example to illustrate this approach is a project that performs a theoretical analysis and evaluation of materials or processes – something that is quite common in computational MSE. Although the scale of funding of such a project would be typically lower than that for a 'final product' project that involves the development and/or application of processing tools, in both cases the 'final product', a program code or a device prototype, would be a required benchmark for success, qualifying the generated knowledge.

Transnational research programmes

As well as promoting collaboration with industry through different R&D projects, European MSE programmes can also strengthen collaboration between countries through the implementation of transnational research activities or the opening of national research and innovation programmes to foreign partners from universities and research centres. Due to the complexity of MSE, these programmes would provide the possibility of bringing together not only different research centres but also industries and academic institutions located in different EU countries. The ERA-NET and EIT KIC programmes constitute a tentative yet interesting step in this direction[17]. However, the lack of common criteria in ERA countries needs to be overcome to make the current ERA-NET instrument more effective.

Infrastructures for R&D in MSE

Processing and other related activities are at the core of MSE, aimed at the goal of innovative applications or manufactured prototype devices. To achieve this aim will require a more successful transfer of knowledge than has hitherto been realised in MSE. Advancement towards timely implementation of innovative devices and prototypes is commonly achieved by exploiting existing state-of-the-art technological infrastructures in Europe. However, large research infrastructures for MSE are commonly associated with facilities such as synchrotron or neutron sources and others where efforts focus on materials characterisation rather than on process analysis or optimisation. Indeed, these 'characterisation' facilities are extremely important and necessary in order to advance fundamental knowledge in MSE. However, it is also essential to provide for the creation and operation of advanced large technology research facilities dedicated to the processing and testing of materials in their final form. These large

17 See https://www.m-era.net and http://eit.europa.eu/eit-community/eit-raw-materials for further details and information

facilities could be organised in (public and private) networks to create a network of different facilities that offer a wide range of services to academia and industry, including SMEs. They together would create Europe's technology infrastructure not only at the frontier of knowledge creation but also at the point of technology validation and proof-of-concept, which could then be readily transferred to industry for prototyping and commercial exploitation. Such networks could consist of facilities such as clean rooms complying with strict specifications, high technology facilities for testing structural materials, for instance advanced laser beam facilities, applied technology centres, and so forth.

3.4 Creation of spin-outs

It is generally accepted that creating spin-out companies is one of the most straightforward paths for the successful transfer of knowledge from academia to the industrial sector. On average, an academic transfer office in Europe promotes the creation of 1.5 spin-out companies, compared with 3.3 in the US.[10] According to a study for the final Complex EIT Report[18] somewhere between 8 and 12 spin-outs are created per year in each of the four European universities surveyed by the study. After 5–10 years, 80% of these companies are noted by the transfer office as still running and active. The most frequent reasons for failure of the other 20% was given as an unentrepreneurial attitude on the part of the spin-out's founder, combined with a lack of entrepreneurship skills. In the US only between 30 and 40% of the spin-outs appear to still exist after a similar period. This difference reflects the greater preparedness within the US to take risks in relation to these initiatives compared to Europe. Risk assessment is therefore a first critical point to be addressed when dealing with spin-out programmes in the field of MSE. In most cases the material is not the end product but part of a system or a device. Risk is perceived to be generally higher in MSE than in other domains (for example for pharmaceutical compounds or chemical processes) because the spin-out is not usually able to deal with the entire value chain to the final products. Acceptance of this higher risk in MSE spin-outs should be a **requirement** to favour the launching of these initiatives.

There are two actions that can be **recommended** to cope with the higher risk potentials in MSE spin-offs:

i. Accepting a higher risk in the business plans (and therefore a higher probability of failure after a certain period of time) and
ii. Integrating more disciplines and expertise into the spin-out to cover as many aspects of the value chain as possible for a given product. Alternatively, the spin-outs can be integrated into research park environments ensuring that all necessary disciplines and expertise are within 'walking distance' (for example technology transfer centres or university research parks).

Another particular aspect of spin-outs in the MSE domain is the possibility that they base their competitiveness not on a new product or material, but on the use of new processing technologies that deliver an advantage over existing manufacturing procedures. In MSE, process development is a strong niche where advances in process knowledge can be directly transferred to the production sector through spin-outs. Effective material fluxes for raw and substitute materials and new advanced materials are other natural niches of activity where the creation of spin-outs can be especially well-suited for the successful transfer of knowledge from academia to the production sector.

3.5 Careers

MSE is a multidisciplinary field. Nonetheless, it is a significant independent field with its own training and skills requirements. This is most evidently seen in the necessity to train scientists and engineers in a unique academic curriculum that extends beyond the traditional confines of physics, chemistry, and so on, to enable them to perform research and development in the field. Yet there remains a significant skills gap[19] in MSE. To close the existing skills gap in Europe requires a redefinition of academic training and the contents of academic curricula so that skills of scientists and engineers trained in academia can match those that are required within the field of materials science (the 'General Materials Scientist') and the materials engineering needs of industry (the 'General Materials Engineer'). The importance of knowledge and technology transfer activities in both academic education programmes and in indus-

18 Figures on start-ups at Lund University, Oxford University, Karlsruhe Institute of Technology, Ecole Polytechnique Fédérale de Lausanne: H. Grimmeiss and P. R. Bressler, private communication. See http://www.complexeit.com/ComplexEIT%20Final%20report.pdf and sections on entrepreneurship therein for a summarised analysis

19 Skills gap reports; see for instance, http://www.brookings.edu/research/interactives/2014/job-vacancies-and-stem-skills, http://www.newskillsnetwork.eu/doc/625, or http://ocw.mit.edu/courses/materials-science-and-engineering/, and *Parliament Magazine*, Oct. 1, 2014, 'KETs can strengthen European industry'

try needs much more attention, and new 'two-way' academic–industrial careers need much more consideration.

The following **recommendations** aim to change the present situation in Europe where, in general, very little career cross-over exists for researchers and engineers to move frequently and freely between industry and production and universities and research centres. Such 'two-way' academic–industrial career cross-overs are urgently needed to enhance innovation creation in MSE.

Incorporate transfer of knowledge issues in student curricula

Where necessary, bachelor/masters/doctorate programmes in MSE throughout Europe should be modified to address the fundamentals of transfer of knowledge and innovation creation within the curricula. Information and motivation of students needs to be strengthened by direct involvement of industry, for example through visits and internships in industry and the attendance of special courses or seminars given by engineers/researchers from industry. The (at least partial) funding of PhD projects by industry needs further encouragement.

Transfer of knowledge through masters or specialisation courses for engineers

Engineers working in industry should be encouraged to participate in special university programmes related to the transfer of knowledge or to attend masters and/or specialisation courses. This would require academic institutions to devise timetables for such courses so that they are compatible with professional working hours.

Alternative criteria for the evaluation of academic careers in MSE

With regard to academic careers, there is a difference between materials science (MS) and materials engineering (ME). Students graduating in MS normally compete in their academic careers with students majoring in physics or chemistry. Due to this situation, the well-established focus on highly ranked publications prevails as the dominant benchmark for promotion and advancement of scientific careers. Some major consequences of this situation are:

1. Under-valorisation of research results in traditional areas of MSE at universities and research centres compared to basic research results in physics, chemistry and computational sciences.
2. Lower reputation of MS scientists and limited academic career tracks compared to scientists in traditional science fields with an orientation towards more fundamental research.
3. Limited transfer of advanced materials research and development into more conventional applications on the part of academia.

Therefore, it is important to base the evaluation of academic careers in MSE not only on academic publications but on innovation-indicative criteria (e.g. patents, prototypes, proofs-of-concept, technology validation success and other technology transfer activities). For example, this could be achieved by:

i. Significantly higher-ranked awards for patents, technology validation and prototyping activities;
ii. Higher visibility and recognition of industrial achievement and appreciation of careers which are partly conducted in industry and partly at university;
iii. Additional salary/bonuses/incentives for co-creation and transfer activities from academia to industry.

Valorisation of careers partially conducted in industry

Two-way mobility between academia and industry is essential and should be encouraged by incentives and less-restrictive legal and regulatory measures, for instance rules concerning social benefits, dual career models and pension schemes. Assurance measures and clear legal regulations are needed to secure employment rights and establish benefits for those professionals who opt to undertake such exchanges.

Implementation of incentives for transfer activities

A variety of different measures can be put in place, for example a reduction of teaching and other tutorial duties, financial bonuses, and so on.

3.6 Intellectual Property Rights: special aspects in MSE

The importance of IP and IP protection in exploiting knowledge for economic return has been highlighted several times in this report. In its initial inception, a patent exists to provide its owner a competitive advantage by preventing others from exploiting the patented ideas or technologies without paying royalties. A straightforward application of IP protection is seen typically in the pharmaceutical and chemical industry where the relationship between an idea, e.g. the effectiveness of a chemical compound for curing a health problem, is directly related to a product, i.e. a drug, which can be sold. The concept of what one might call blockbuster IP falls short in industry sectors with high manufacturing complexity. A typical example is the information technology (IT) industry. Here, partners have formed what might be termed an open innovation community in which IP is shared between the partners through cross-licensing agreements. The driving force behind cross-licensing is the fact that product innovation can only be achieved by applying the cumulative knowledge from various stages in the innovation and value chains. This requires the complementary technological know-how to be shared between the partners. In this model patents have a totally different role than is traditionally the case. They do not serve the purpose of preventing competitors from using the patented ideas but rather as trading chips, to gain the rights to utilise ideas and technologies created by others.

The academic research and development community has put substantially more emphasis on seeking patent protection for its work over the past years by adopting a blockbuster mentality. There is a controversial discussion around the question of whether universities are behaving like 'patent trolls'. The trend has been fuelled by some spectacular success stories which have been reported in the public domain.[20] By its very preventive nature, the trend is counteractive towards collaboration and one may reasonably ask the question of whether this is an economically sensible approach. The role of publicly funded institutions should rather be to create a pool of findings and validated concepts that may or may not represent economic value, but offer even more value when bundled together. This is particularly true in complex fields such as MSE. Similar to the case of the IT field, public R&D could be seen as an open innovation community, with a subtle difference, however, in that public R&D institutions are not innovators. They do not create new products. A priori they would have no incentive to gain access to other patents, and the patent portfolio would not function as an exchange currency for ideas. That is, of course, only if they do not enter a public–private innovation partnership, in which the open innovation model makes sense for them after all. There, they would make available their protected ideas for testing by technology developers. Complex technologies can then be developed and validated, and new products and services can be envisioned and handed over to the prototyping partners, after which the commercial ramp-up and exploitation can start, generating returns for all partners. Such an open innovation community is a unique public–private partnership, in which the public domain can participate in the innovation and economic value process.

For the first part of the last century basic research was a working market model for high-tech companies that conducted their own basic research and exploited the results commercially. Those were the days of large commercial research labs (Bell labs, RCA labs, Philips research labs, among many others) owned and operated by the high-tech companies of the day, IBM, Bell, RCA, Philips, AEG, General Electric. Fundamental research findings were made in those labs and exploited by the companies. The second half of the last century saw the rise of publicly funded large national laboratories, followed by research universities which expanded their fundamental research programmes and scaled up their basic research applications. Their results were published in scientific journals and were therefore made readily available. As a result of this trend, the company research laboratory business model collapsed, basic research became a market failure and most of the famous research labs became extinct. Instead, industry had relatively free access to the publicly funded research pool and could even file exclusive patents resulting from collaborations with public partners. By the early 1980s new legislation (for instance, the Bayh-Dole act in the US) granted the IP rights by default to the publicly funded entity (typically universities or national labs) involved, in an attempt to encourage public ownership of publicly funded research. This somewhat curbed public–private research cooperation but created more awareness at universities of IP rights and the potential exploitation of IP. Nowadays, spin-out companies from research labs and universities play an increasingly important role in the commercialisation of research results created through public funding. Using open innovation and the concept of cross-licensing, this commercialisation path will gain increasing traction in the future. Public R&D institutions should be encouraged to engage in a cross-licensing pool in which their spin-out companies can take a stake. In this way, the economic value of IP created by public institutions can be substantially augmented. Patent pools can grant open-innovation communities comprising several spin-outs and companies wider access to a range of technologies for new products and joint product development.

20 See, for instance: http://www.nature.com/news/universities-struggle-to-make-patents-pay-1.13811, http://www.slate.com/articles/technology/history_of_innovation/2014/05/patent_trolls_universities_sometimes_look_a_lot_like_trolls.html, and http://www.ipwatchdog.com/2014/06/06/universities-are-not-patent-trolls/id=49951/

4. Recommendations for a European technology research and validation infrastructure

We will conclude and summarise our analysis by suggesting measures to improve the European landscape of technology research and validation. The current status of Europe's knowledge and technology transfer in MSE gives rise to the set of recommendations presented in the previous chapters. The analysis also suggests some concrete measures for action in Europe: to accelerate the transition of results of fundamental and technological research in academia into (KET-based) new products, processes and services of innovative commercial value by a more effective link between the (academia-closer) stages of *initial technology development*, *technology integration*, *proof-of-concept* to *technology validation*, and thereafter to 'downstream' commercialisation.

First, let us provide some definitions of the terms we will need to describe 'technology validation platform' and 'European technology research and validation infrastructure' and to suggest a 'European Technology Research Validation Infrastructure Initiative'.

Technology development, in general, is the "*systematic work that translates acquired knowledge into technology and that is directed towards developing new materials, products, processes or services*" (see also OECD definitions[21]).

Technological development is the process of guiding a basic research finding into a concept for a technology, and then 'into maturity' by performing the tests that either yield a positive 'proof-of-principle', i.e. the feasibility of prototype production and the innovation potential in a relevant environment, or a negative outcome at an early stage.

Technology integration blends successful concepts and technologies into new hybrid technologies. It requires similar feasibility tests and an analysis of the innovation potential as the go-ahead for further development. Technology integration builds on patent pools and open innovation.

Technology validation[22] means testing and assessing the (integrated) technology concepts, providing all tests for the proof-of-principle, successful deployment of the technology in a relevant environment, and assessment/documentation of the feasibility and innovation potential of the new (integrated) technology. This requires prototype production in an environment 'as realistic as possible'. To be innovative, a new hybrid technology must yield better or cheaper products, processes or services than pre-existing technologies. Technology validation delivers the data needed to decide on the construction of pilot lines and demonstrators.

The process of technology validation is crucial for the assessment of innovative potential. Validation must be completed as fast as possible and lead as close to the market as possible. This requires the collaboration of research institutions,

21 See, for instance, Frascati Manual, OECD 2002, ISBN 9789264199039

22 See, for instance, http://esto.nasa.gov/files/trl_definitions.pdf. The concept of technology validation is integral to the concept and definition of technology readiness levels (TRLs). A discussion of technology readiness levels can be found in reference 2

development laboratories and high-tech companies (high-tech SMEs and industrial manufacturers). Such a network or platform will need at its disposal a wide range of scientific and technological equipment and facilities to share and complement the necessary validation tasks, as well as the financial means (VC and investors) to cross the valley of death. Such a consortium represents a **technology validation platform (TVP)**.

4.1 European Technology Validation Platform

To accelerate the development of new technologies from the research stages of the innovation chain to the creation of pilot lines, prototypes and demonstrators, one needs:

- A broad network of well-equipped applied science and technology developers (research institutes and SMEs) capable of covering most links of the innovation chain, i.e. to provide the necessary scientific and technological equipment and facilities to validate a wide range of technology concepts.
- An appropriate network of technology-based commercial enterprises and investors to co-develop demonstrators with the additional capacity to attract the necessary financial critical mass for large-scale production inside the EU.
- A fast-track project-funding programme for the quick conversion of ideas for new technologies to proof-of-concept tests and to prototypes based on new innovative technologies. A programme coordination centre or common entry point takes proposals for new tests or applications of technologies, assesses their impact and feasibility, and provides technology partners within the platform to carry out the technology validation in an open innovation model[23]. After proof-of-concept, validation and prototyping, small-scale production (on a pilot line) can be picked up with commercial partners. The programme will also provide a powerful organisational umbrella and tools to secure the IP developed in an open innovation model.

Validation platforms can be created by combining existing national/regional technology clusters which each have state-of-the-art instrumentation/equipment for analysis, testing and production in one segment of the validation platform. Subsequently, the network is expanded and opened to additional partners so that it grows into a broad-based technology validation platform (TVP). The platform provides the necessary validation services to external developers. These TVPs can be linked to other TVPs with the goal of broadening further the technology toolbox to include emerging interdisciplinary fields or technologies. Such an alliance of two, three or more TVPs must commensurately expand its production-oriented commercial network to become a Technology Validation Infrastructure.

We propose European Technology Research and Validation Platforms for Materials Science and Engineering under the coordinated action of MSE champions in Europe to develop the proof-of-concept, production tests and pilot line demonstrators together with an evaluation of the subsequent large-scale production business model for new integrated technologies. The results feed directly into business models for initial production based on public–private collaboration and partnerships.

Candidate clusters and criteria

Europe has several applied research institutes and commercial technology developers that have already formed regional clusters of excellence, specialised to develop, integrate and validate applications for key enabling technologies (KETs). On a global scale a number of these existing technology clusters and validation platforms are first class and highly competitive and possessing state-of-the-art facilities. These clusters – or platforms – are usually based on regional models serving regional technology partnerships with private technology stakeholders, dedicated to technology transfer. However, they often lack the broad services and technology range needed to tackle multi-KET development. Likewise, their commercial networks often lack the potential for critical mass in a multi-technology setting.

Existing partnerships in Grenoble (LETI, Minatec, STmicroelectronics and others) or Dresden (Global Foundries, Infineon, Fraunhofer and others) are just two examples of state-of-the-art technology clusters capable of blending cutting edge applications using micro- and nanoelectronics, photonics, nanotechnologies, and advanced materials in advanced manufacturing environments. There are several other examples in all KET areas.

Technology platforms for technology development, integration and validation in Europe should be invited to link with other complementary clusters to create the Technology Research and Validation Infrastructure in Europe.

23 For instance, H. Chesbrough, '*Open Innovation: The new imperative for creating and profiting from technology*'. Boston: Harvard Business School Press. ISBN 978-1578518371, or C. Schutte, S. Marais (2010), 'The Development of Open Innovation Models to Assist the Innovation Process'. University of Stellenbosch, South Africa

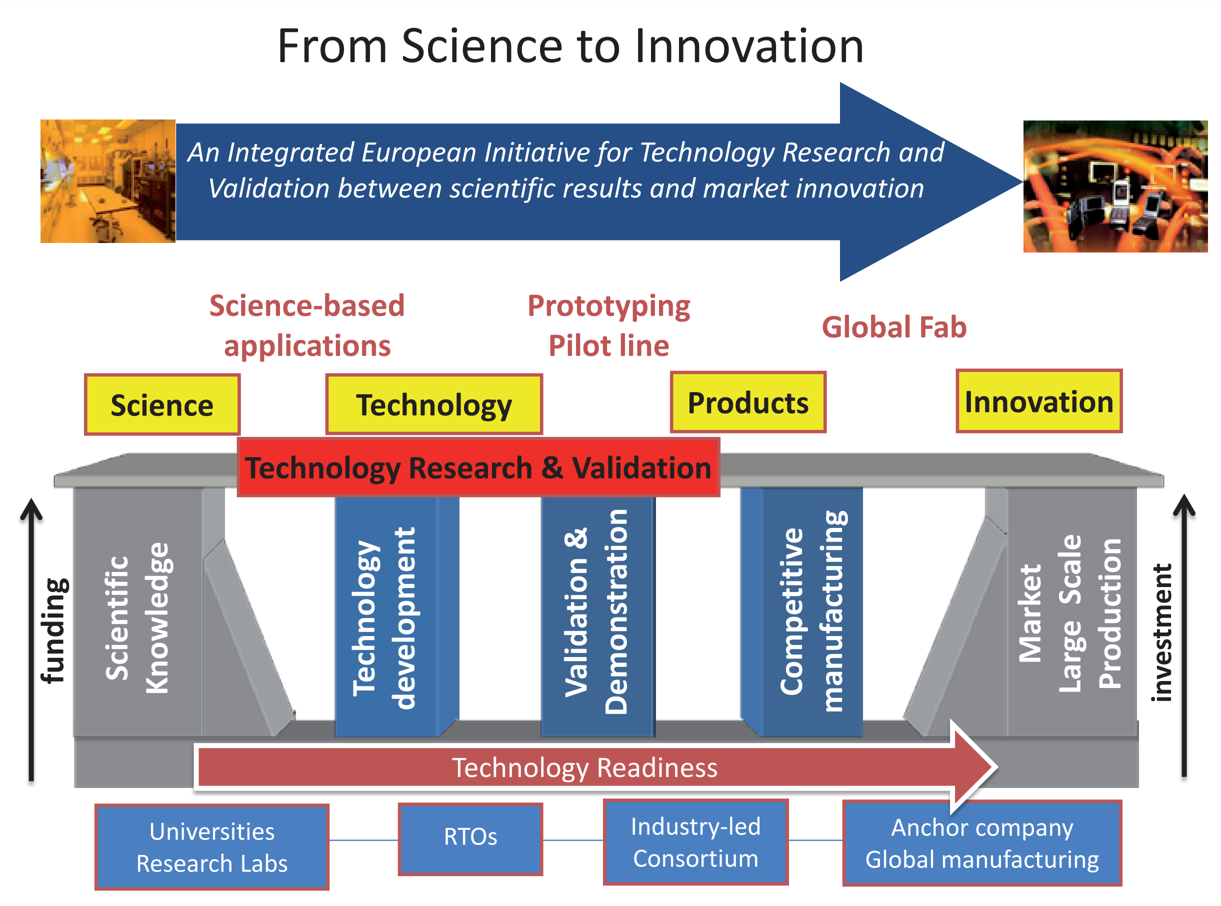

Diagram 1. Technology Research and Validation Initiative for Technology-based Innovation in Europe. Courtesy P. Bressler

A Technology Research and Validation Infrastructure provides proof-of-principle and technology validation services to external customers in a wider range of technology applications along with the commercial links to finance market introduction. Completeness and the speed that the Technology Research and Validation Infrastructure can provide are crucial and significant criteria. The suggested model for fostering technology validation and engagement from SMEs from all over Europe can be seen as similar in governance and implementation to the existing Integrated Infrastructure Initiatives (I3s) of the European Commission for large-scale research infrastructures dedicated to basic research[24].

4.2 Open-Access-Open-Innovation for Materials Science and Engineering: An Integrated European Technology Research and Validation Infrastructure Initiative to fund technological research, development and validation across Europe

The consortium sets up a central management office to run the Technology Validation Infrastructure Initiative. The goal is to grant European technology developers from commercial technology firms, start-ups or other research labs access to the state-of-the-art technological facilities and equipment within the Technology Validation Infrastructure to test integrated applications of key technologies on a proposal-based, reviewed open innovation model. To carry out the work the successful proposers (external technologists) and the host facilities involved enter a standardised cooperation contract.

The core management of the infrastructure offers and arranges the joint collaboration and organises the use of the infrastructure's equipment and facilities. Within the joint project the collaborative team carries out the development and testing work and

24 I3s: http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=existing_infra

validates the proof-of-concept data. The infrastructure will provide the necessary business expertise to help assess the feasibility of the pilot line construction and ramp-up production. Where deemed feasible the infrastructure will provide the business arrangements necessary to enter the next stage with the commercial partners of the initiative. This next stage is the prototyping. It will be governed by the standardised agreements on commercial exploitation of the Technology Validation Infrastructure.

An 'Open-Access-Open-Innovation' Initiative will encourage an influx of ideas and concepts for new technologies, technology integration, and new products and services by the external team members. The initiative provides the technology experts needed to balance the team, the best testing facilities and the best technical equipment available for a fast validation. The infrastructure also provides standardised IP agreements and business expertise. A European Technology Research and Validation Infrastructure will include at least three elements:

1. A joint technology research and development programme between the sub-clusters or research facilities within the infrastructure. The programme shall enable joint technology projects to improve the capacity and state-of-the-art of the technology hardware and analytical services that the infrastructure provides.
2. A joint education and training programme for internal and external experts to enhance their fundamental and technical knowledge, and to train new experts.
3. An external access programme for technology development and validation projects (technology validation projects) proposed by external high-tech SMEs, individual technology developers or others. Technology development and validation proposals are submitted under a non-disclosure agreement. The programme allocates successfully reviewed projects access to external technology developers, scientists and entrepreneurs on an open innovation basis.

Technology Validation Projects can be carried out by (geographically distributed) collaborative teams of external proposers and internal experts of the Technology Validation Infrastructure. Technology development and testing is performed with the best infrastructure services and instrumentation available. The best 'machines' and 'machine time' become available, even to researchers and entrepreneurs in less-favourable regions, to test new ideas and to develop new applications where feasible. Funding is provided for access to the facilities, on-site visits and to explore subsequent stages. Operational costs directly related to the project are covered through the programme funding on a not-for-profit full-cost model. An exploitation plan, based on cross-licensing IP and 'Open Innovation' is mandatory and to be included in the proposal. European Technology Validation Infrastructures offer a unique pathway for technology-driven innovation.

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