European Commission

Innovation

How to convert Research into Commercial Success Story?

Part 2 :
Analysis of innovation successes in the field of industrial technologies

Written by

pwc

Research and Innovation

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Innovation
How to convert research into commercial success story?

Part 2: Analysis of commercial successes induced by innovation in the field of industrial technologies

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Table of contents

Executive summary

The current report represents the Final Report for Lot 2 of the study on "Open innovation and enabling technologies: Analysis of conditions for transfer of knowledge" (service contract nr NMP1-SC-2011-IN0002) prepared by PwC for Directorate-General for Research & Innovation of the European Commission (hereafter "DG RTD").

The study aimed to shed light on the question of how to best fund research projects in the Nanoscience, Nanotechnologies, New Materials and Production Processes (NMP) area to promote and improve the exploitation of results. The report provides recommendations on how to increase the innovation output in the Seventh Framework Programme (hereafter "FP7") project cycle and in the future Horizon 2020 Programme (hereafter "H2020"), and in particular, how to foster innovation at all the stages of the project cycle, expand the exploitation side of projects, and improve the entrepreneurial strategies and capacities of Project Partners.

The study implied the analysis of the commercialisation path of thirty global innovation showcases both within and outside Europe, and relied on extensive fieldwork. The study focused on innovations not explicitly financed by the EU programmes. The fieldwork consisted of several steps including exploratory interviews followed by a series of in-depth interviews. Detailed case study descriptions were developed for each case including the information on:

- The traceability of the process from the introduction of those innovations up to their technical source, their diffusion time and pattern;
- The factors explaining or easing the implementation and success of these innovations;
- Obstacles that have been encountered during the diffusion and implementation phase after completion of work at research/technology level, and how those have been overcome;
- Channels of dissemination of technical information.

The analysis part included recalling the initially formulated hypotheses, examining their manifestation in specific cases, and drawing general trends across each specific category. An extensive list of success markers was then developed. Success markers aim to show what proves to be vital in determining whether an innovation will be successful on the market or not, and consequently indicate areas that require special attention from the policy makers' side.

Key findings and conclusions

The key general conclusions of the study can be summarised as follows:

- NMP is fast becoming an important business area for companies in a diverse range of industries. It is expected to have a major influence on virtually all sectors where materials play a role, such as aerospace and defence, electronics, energy, life sciences and healthcare, textiles, environment, water, food, construction, consumer goods, household care, security, automotive, chemicals and coatings.

- NMP innovations imply complex, multidisciplinary and potentially disruptive nature of the innovation cycle. NMP market is not a single market but a series of enabling technologies that provide groundbreaking solutions to critical challenges in various industries.

- Products based on NMP and enabling technologies in general often draw not simply upon multiple innovations, but upon multiple innovations from various disciplines.

- All NMP innovations can be split into three main categories: New Products, New Materials and New Production. Our empirical analysis confirmed the *significant differences* between the progression of innovations within these three categories.

- New Products and New Materials categories proved to have somewhat comparable innovation trajectories. A key difference refers to the fact that the innovation trajectory of New Materials typically feeds into the innovation trajectory of New Products. Additionally, since materials are embedded in products, any risks that exist in the product market are amplified in the materials market.

- In case of New Production, one has to deal with different types of activities, decisions and challenges when compared with New Products and New Materials, and these differences should be taken into consideration when developing effective policy measures.

- Rather than being a chain of subsequent steps, the NMP innovation trajectory represents a continuous process with close interrelations between various parallel activities. While from a strategic perspective, the objective of these activities remains the same all the time, the way these activities are performed operationally evolves over time.

- An activity playing a key role in the innovation trajectory refers to the interaction with users, designers and engineers, which, in case of successful innovations, happens throughout the whole innovation process.

- Successful NMP innovations result from a combination of both technology push and market pull, i.e., there needs to be a clear demand for the innovation, but at the same time, the technology should be at the level that is advanced enough to satisfy that demand and to create new markets.

- Companies typically try to introduce the NMP innovations to the market as soon as possible. However, if the innovation falls under a highly regulated sector (e.g., healthcare sector, such as medical devices, equipment or treatment), time-to-market significantly increases because of regulatory requirements.

- The development of NMP innovations from the sample was often mainly supported by private funds coming from own savings, company's own funds and business angels in the beginning, and venture capital investors at later stages. However, private funds were often triggered by the use of public funds, which corresponds to the concept of 'smart' public funding.

- The public funds used by the analysed cases primarily included national funding such as grants for joint research projects between university and industry by national ministries, tax deduction schemes for R&D activities, loans with governmental guarantees, and other measures stimulating interaction and exchange between the universities and SMEs. Some of the analysed cases benefited from public support for the activities closer to the market which can partially explain the success of the exploitation of their research results.

- The successful NMP innovations are highly flexible, i.e., they are designed in such way that it is easy to respond to the rapidly changing environment and to incorporate user feedback.

- Other key factors determining the success of the innovation refer to so called human factors or people standing behind the innovation, which includes charismatic leaders and intrinsically highly motivated teams.

- When comparing EU and non-EU cases, hardly any differences were detected between the successful cases from different world regions with regard to both micro- and macro-level factors. There is a set of common trends that can be observed among the majority of the global innovation showcases despite their geographical location.

- At the micro-level, those trends among others include highly motivated teams and charismatic leaders, active early engagement with end-users and good access to private funds.
- At the macro-level, the role of regulation proves to vary depending on the sector of the innovation. While eco-friendly innovations typically benefit from the environmental legislation and get accelerated by it, innovations related to, for example, medical devices, equipment or treatment, often face a considerably increased time-to-market because of complex safety requirements.

The evolving activities of the innovation cycle can be linked to specific Technology Readiness Levels (TRLs). This internationally recognised and industrially applied concept outlines in detail the different research and deployment steps, which support the innovation and industrialisation process of technologies to transform ideas to the market. In total, nine TRLs can be distinguished. At the lowest TRL (TRL 1), ideas are transitioning out of fundamental research into applied research and development. At the highest TRL (TRL 9), the technology is ready for its deployment.

Below we highlight only the key issues for each of the specific innovation activities. For a detailed overview of findings and conclusions, the reader is advised to consult Chapter 3 of the Report.

Activity 1 Research: the key research-related challenges refer to availability of knowledge within the company/team; the need to tackle technical problems nobody ever tackled before; and the need to balance between quality and price due to budget limitations.

Activity 2 Interaction with users, designers and engineers: this involvement may take different forms such as online collaboration platforms; direct contacts with users; web blogs and emails; engagement in open source approach etc. The form chosen depends on the development stage of the innovation, type of innovation, and resources available for such interactions. Companies often actively use their first buyers to collect valuable feedback that would be later translated into significant improvements of the innovation.

Activity 3 Exploring market opportunities: companies explore the market by means of either relatively simple Internet search or by following a more rigorous approach including intensive communication with potential competitors and customers.

Activity 4 Protecting and managing Intellectual Property Rights: different scenarios are possible regarding the creation of IP for NMP innovations, and there is no one best way to deal with IP. It depends, among others, on whether IP already exists or needs to be created, the risk of substitution, as well as the size and financial capacity of a company.

Activity 5 Prototyping and industrial demonstration: a prototype is a necessary prerequisite for a successful innovation. To understand a real technological concept, the buyer often needs to see the product that has the technology imbedded in it. The prototype stage involves close contacts with customers and collaboration partners. Companies prefer to carry out prototyping activities in house.

Activity 6 Product trials and sales: to achieve a competitive advantage, companies may claim that their product is of unique nature. Some companies chose high price strategy. In other cases, the product had to be made affordable to penetrate the market. When developing marketing strategies for NMP innovations, there is a need to embrace a broader concept of innovation, including its non-technological aspects such as design, creativity, service, communication, process and business model innovation.

Activity 7 Industrialisation: key success factors here include careful selection of an external manufacturing company which could provide detailed feedback; working with small-size partners allows for making decisions quickly; and working with used equipment through Internet auctions.

Activity 8 Managing innovation: successful NMP innovations imply the involvement of multidisciplinary teams and the engagement of diverse stakeholder groups (e.g., actors of the market, actors of the value chain, partners in research projects, public actors, etc.). Managers of successful NMP innovations grant a considerable amount of freedom to the team to conduct research and develop the innovation.

Recommendations

The key recommendations can be grouped into the following three categories:

(1) Recommendations on the process improvement for FP7- and future H2020-related actions from a project management perspective;

(2) Recommendations on supporting technology push of NMP innovations;

(3) Recommendations on supporting market pull of NMP innovations.

Below we present the key recommendations per category.

Category 1: Recommendations on the process improvement for FP7- and future H2020-related actions from a project management perspective

- ***Introducing evidence-based systematic framework for NMP project selection, monitoring and evaluation:*** the quality of the decision making with regard to the funding of NMP projects can be improved by advancing the *quality* and *relevance* of the information base such decisions rely on. The latter, in turn, can be achieved by means of introducing a systematic approach for project selection, monitoring and evaluation. Rather than being separate unrelated exercises, project selection, monitoring and evaluation need to be closely interlinked in one framework and serve one overarching objective of understanding the chances of commercial success of the funded NMP innovation and obtaining knowledge on how to increase those chances.

- ***Taking into account the continuous and evolutionary nature of innovation activities***: for the initial FP7/H2020 project assessment, as well as monitoring and final evaluation to be successful, the notion of the continuous and evolutionary nature of innovation activities needs to be put in the central position to realistically reflect the NMP innovation trajectory. Despite its continuity, the innovation trajectory can be split into several phases (see Figure 0-1) and allows for setting milestones and developing key indicators for each phase.

- ***Aligning the NMP RDI activities with the Technology Readiness Level (TRL) scale:*** the internationally recognised and industrially applied concept of TRLs outlines in detail the different research and deployment steps, which support the innovation and industrialisation process of technologies to transform ideas to the market. For the TRL scale to be effectively adopted by the Project Officers (hereafter "POs") and Project Technical Advisers (hereafter "PTAs"), ***targeted training sessions*** could be organised to outline the essence of the TRL scale, as well as its applicability to specific technologies and to the initial FP7/H2020 project assessment, monitoring and final evaluation.

- ***Integrating success markers into FP7/H2020 project cycle***: the proposed success marker tool (see pages 16 - 19) allows for screening for different success markers at different phases of the evolving innovation, while constantly addressing the same types of activities (e.g., research, innovation management etc.). Consequently, at each phase of the innovation's development, the screening is focused on the markers that matter most for the innovation's success at that particular phase. A different set of success markers has been developed for New Production category of

NMP innovations due to a conceptually different nature of these innovations.

- ***Developing a standardised point system***: the identified success markers can be operationalised into a set measurable items. These items can be measured in actual numbers or in the form of a scale. This approach allows for developing a point system, with sub-total scores per project activity, and total scores per project phase. Establishing thresholds would allow for detecting projects that are well on track, as well as the ones that are off the trajectory potentially leading to a commercial success. Such information, in turn, would provide an objective basis for funding-related decisions.

- ***Communicating the new framework to Project Partners***: the success markers specify the ways and conditions for transfer of knowledge from research projects to the market, as well as on how to ensure the marketability of innovations. To ensure a full alignment between the expectations of project evaluators and the actions of Project Partners, the identified success markers have to be effectively communicated to the Project Partners well in advance. Three key recommended ways of communicating these guidelines to Project Partners by DG RTD include the following: incorporating success markers into FP7/H2020 Guides for Applicants; incorporating success markers into ESIC (Exploitation Strategy and Innovation Consultants) support programme; and disseminating the information on the success markers via RTD NMP Innovation Platform.

Category 2: Recommendations on supporting technology push of NMP innovations

- ***Funding innovation cycle in multiple phases***: public funding typically decreases throughout the innovation cycle, with an opposite trend for private funds. At the same time, the costs associated with the innovation cycle increase steadily from basic research up to product development. NMP innovations require a consistent multi-year programmatic approach split into several phases.

- ***Extending funding towards closer-to-market activities***: such activities include prototyping, testing, demonstration and validation. Already at the proposal stage, Project Partners should be encouraged to address the issues of the exploitation and market take-up of innovative solutions.

- ***Supporting high-tech SMEs with a new SME instrument:*** the instrument aims to fill the gaps in funding for early-stage, high-risk research and innovation by SMEs, as well as stimulating breakthrough innovations. This new instrument will synergise with the RSFF[1] and the CIP[2]-connected horizontal instruments (GIF and SMEG) facilitating access to risk finance and venture capital. The success markers developed by this study could form the base for the monitoring and evaluation activities of this new instrument, the activities that inevitably need to be put in place to be able to judge on the progress (monitoring) and success (evaluation) of each phase.

Category 3: Recommendations on supporting market pull of NMP innovations

- ***Encouraging interaction with end-users:*** interaction with end-users strengthens the innovation's ability to quickly adapt to new market demand or circumstances. The feedback provided by the end-users signals the areas where rapid improvement is needed, and of that information is taken onboard, the likelihood of commercial success considerably increases. Consequently, interaction with end-users should be encouraged within FP7/H2020 projects in order to enhance short- to medium-term market impacts. An approach towards the interaction with end-users should be already sketched in the initial project proposal and embedded in project planning. It should also form the part of the proposal assessment.

- ***Going beyond technological innovation:*** for KETs in general and NMP innovations in particular, there is a need to embrace a broader concept of innovation, including its non-technological aspects such as design, creativity, service, communication, process and business model innovation, i.e., social innovation. Social innovation goes hand in hand with NMP technological innovation, and proves to be decisive for successful market entry and commercial growth. The aspects of social innovation therefore need to be included in the evaluation of the quality of the future NMP projects, including project selection.

- ***Stimulating (pre-commercial) public procurement:*** by acting as technologically demanding first buyers of new R&D, public procurers can drive innovation from the demand side. This enables public authorities to advance the provision of public services faster and creates opportunities for companies to take international leadership in new markets. This approach is already widely used in the United States and Japan as an important mechanism to stimulate innovation. Pre-commercial public procurement has also been recently introduced in Europe and needs to be expanded. Pre-

[1] Risk-Sharing Finance Facility, see http://www.eib.org/products/rsff/index.htm
[2] Competitiveness and Innovation Framework Programme, see http://ec.europa.eu/cip/

commercial public procurement is, however, not equally relevant for all industrial sectors.

- ***Enhancing the link between regulation and innovation:*** in order to respond to the society's concerns, it is of crucial importance to maintain a dialogue on benefits and risks of NMP innovations, including ethical, legal, societal aspects as well as environment, health and safety aspects, involving great parts of the public and basing on informed judgement. At the same time, recognising the potential societal and economic benefits of NMP innovations, policy makers need to encourage R&D, increase possibilities of practical application, and to ensure their safe utilisation and public acceptance. Regulation in this case represents a powerful tool to achieve these objectives.

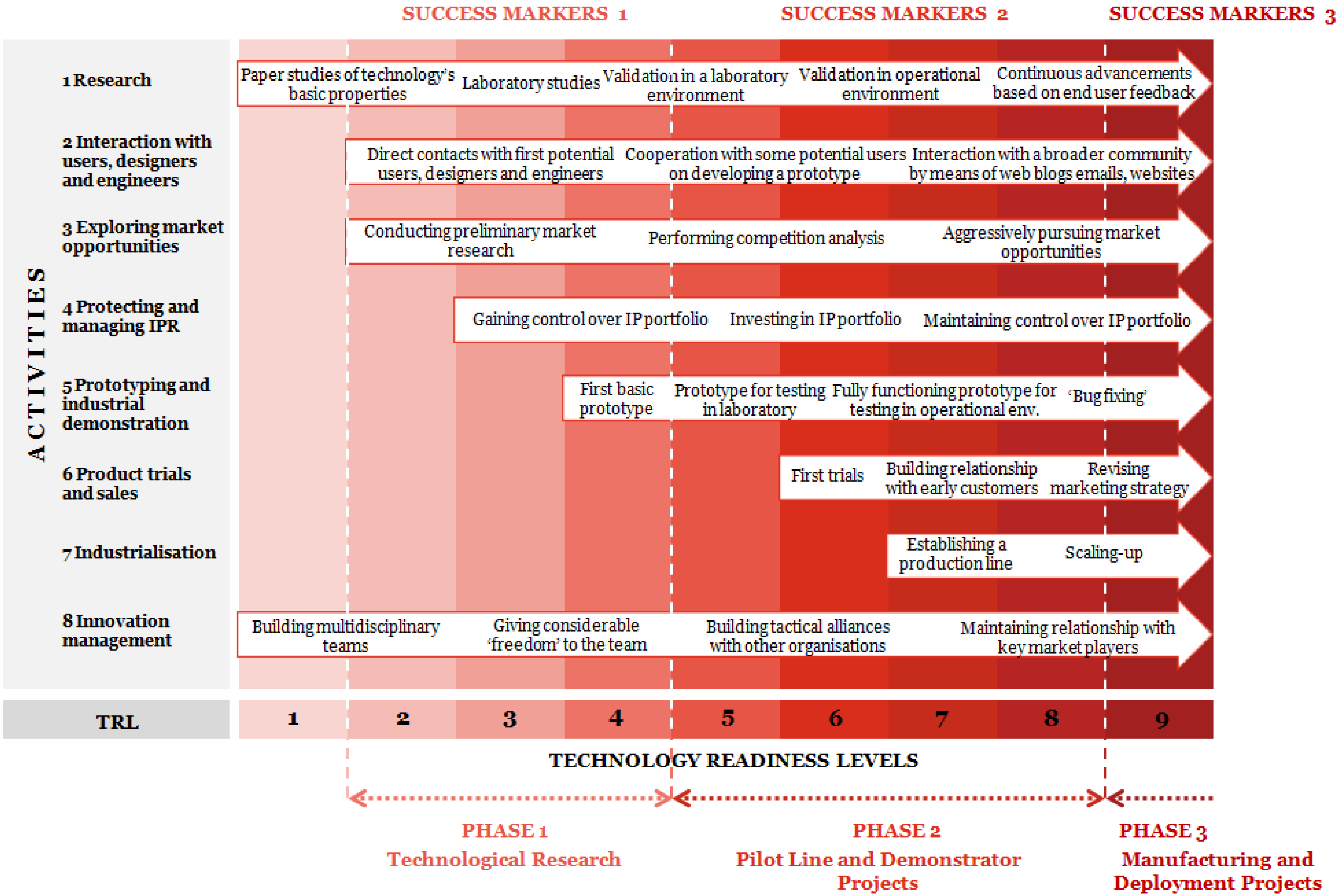

FIGURE 0-1: Proposed evidence-based systematic framework for NMP project selection, monitoring and evaluation

TABLE 0-1: Success markers for NMP Products and Materials (1 – totally inapplicable to this project; 3 – partially applicable to this project; 5 – fully applicable to this project)

Nr	Activity	Success marker	1	2	3	4	5
Phase 1 (TRL 2-4)							
1.1	Research (1)	Research from its early stage is closely linked to feedback incorporation from end-users and exploration of market opportunities.					
1.2	Research (1)	The project team (consortium) uses research facilities of a participating university/research center which allows for access to unique and expensive equipment.					
1.3	Research (1)	Both technology push and market pool are present simultaneously, i.e., there is a clear demand/market for the innovation, but at the same time, the technology is at the level that is advanced enough to satisfy the existing demand and to create new markets.					
1.4	Innovation management (8)	The research team consists of highly motivated and highly skilled people with talent and passion for this specific research.					
1.5	Innovation management (8)	When research is conducted by a company, CEO shows commitment and support to the project (including allocation of company's funds). When research is conducted by a university/research institute, the commitment is shown by the head of laboratory/department.					
1.6	Innovation management (8)	Much freedom is granted to the team to conduct research and develop the innovation.					
1.7	Interaction with users, designers and engineers (2)	An active involvement of a broad community of users, designers and engineers begins as direct contacts at company's premises, conferences, fairs and/or other events.					
1.8	Exploring market opportunities (3)	There is a good understanding not only of the market for that particular innovation, but also of the agendas and markets of its potential buyers.					
1.9	Exploring market opportunities (3)	There is a good knowledge of the relevant regulatory and standardisation aspects, and the identified market opportunities are assessed in light of the latest developments.					
1.10	Protecting and managing IPR (4)	Through non-disclosure, consortium members are obliged to keep sensitive information confidential and ensure any disclosure of such information is done in confidence and with prior permission[3].					

[3] See also http://www.innovationtoolbox.com.au/manage-intellectual-property/5-protecting-ip

1.11	Protecting and managing IPR (4)	The IP rules take into account the mission and legitimate interests of both public research institutes and participating industrial partners.					
1.12	Protecting and managing IPR (4)	Internal procedures are established to review organisational publications including journal, presentations, brochures, posters, correspondence, press releases and other forms of public disclosures and this material is reviewed each time before release.					
1.13	Protecting and managing IPR (4)	The maintenance of systematic records of all developmental or experimental work is performed (which is beneficial for IP protection purposes, either in enforcing infringement of others or defending infringement claim by others). Good record-keeping includes using bound notebooks, with pages consecutively numbered, dated, signed and witnessed, chronological, thorough and written using permanent ink.					
1.14	Protecting and managing IPR (4)	Once the decision has been made to proceed with IP protection, an IP lawyer or attorney is professionally engaged to assist with the formal protection and advisory work.					
1.15	Prototyping and industrial demonstration (5)	First basic prototype is developed. The prototype still has a research status, but it is moving from purely theoretical calculations toward a proof in reality as tests are being verified and the results can be seen in a laboratory.					
1.16	Protecting and managing IPR (4)	By the beginning of the prototyping activity, proprietary control via patent or other IP protection mechanisms is established.					
1.17	Innovation management (8)	The team is open for ideas from outside (open innovation concept).					
Phase 2 (TRL 5-8)							
2.1	Research (1)	Success markers helping to attract funding include the charismatic nature of the entrepreneur (e.g., the ability to convince and negotiate), technically well-prepared presentations, rigorous market research, and well thought trough marketing and pricing strategies.					
2.2	Innovation management (8)	Consortium managers serve as a catalyst and coach, keeping everyone focused on the end goal and making sure the team is doing whatever it takes to overcome the powers/inertia that hold back the innovation.					
2.3	Interaction with users, designers and engineers (2)	First (potential) buyers are used to collect valuable feedback that will be later translated into significant improvements of the product.					

2.4	Exploring market opportunities (3)	Segmentation of competitors is performed before entering the market.					
2.5	Exploring market opportunities (3)	Market penetration strategies are assessed in light of the latest regulatory and standardisation developments with the aim to minimise the negative effects of the relevant regulatory barriers and to maximise the benefits of the relevant aspects supported by the regulation and standards.					
2.6	Protecting and managing IPR (4)	Clear agreements are made with suppliers and manufacturers (e.g., restricting the agreement to a certain technology field; restricting the agreement to a certain application or market field; restricting the agreement in time).					
2.7	Product trials and sales (6)	Active contacts are made with potential customers and collaboration partners. First product trials are performed by customers.					
2.8	Protecting and managing IPR (4)	An analysis of intellectual asset portfolios is performed, and programs for their monitoring and enforcement are developed and implemented.					
2.9	Protecting and managing IPR (4)	A review of the opportunities for investing in acquisition or creation of different forms of IP is performed. This stage also involves the application of corporate investment policies and practices to IP management investments for creating a platform for other investment priorities.					
2.10	Prototyping and industrial demonstration (5)	A broader user and engineer community is involved in advancing the prototype.					
2.11	Prototyping and industrial demonstration (5)	An industrial demonstrator allows to understand, identify, and prevent failures before the manufacturing stage is reached. Possible failure modes in different environments are thoroughly tested to ensure that failure model predictions are verified.					
2.12	Product trials and sales (6)	The innovation is clearly named (i.e., it has a catchy and easy-to-understand name) and framed (i.e., it specifies who it is for and what it is for).					
2.13	Product trials and sales (6)	The innovation offers its early adopters a clear comparative business advantage, e.g., lower product costs, faster time-to-market, more complete customer service.					
2.14	Product trials and sales (6)	A specific niche market is targeted where the innovation can force its competitors out of the market niche, and then use it as a base for broader operations.					

Phase 3 (TRL 9)							
3.1	Research (1)	The end-product is continuously updated based on user feedback and latest research results.					
3.2	Interaction with users, designers and engineers (2)	Interaction with users grows into online collaboration platforms with a broader community; web blogs and emails; engagement in open source approach.					
3.3	Industrialisation (7)	Careful selection of an external manufacturing company is made which could provide detailed feedback on product design. Working with used equipment through Internet auctions to reduce costs. Working with small-size partners allows for making decisions quickly.					
3.4	Protecting and managing IPR (4)	Information technology tools are used to capture and manage critical intellectual asset portfolio information in order to sustain IP profits and protect existing IP investments.					
3.5	Prototyping and industrial demonstration (5)	An industrial demonstrator takes into account all stages of manufacturing and includes all aspects of packaging to achieve a successful end product.					
3.6	Product trials and sales (6)	To penetrate the initial target segment, direct sales are (often) used. Once the segment is aware of the innovation's presence and leadership, the transition is made to the most efficient channel for that particular case.					
3.7	Exploring market opportunities (3)	Market opportunities are pursued aggressively. However, if the target market is too large to be approached directly, then less aggressive measures are also mobilised (e.g., participation in scientific events, publications, brochures, newsletters and fairs).					
3.8	Exploring market opportunities (3)	The results of the market strategy are carefully monitored, and adjustments introduced if needed. Market strategy is periodically reassessed also in light of the latest regulatory and standardisation developments.					
3.9	Product trials and sales (6)	The innovation's transition from an early market to a mainstream market implies a complete revision of the market strategy (positioning, segments, pricing etc.).					
3.10	Product trials and sales (6)	When targeting a mainstream market, the innovation's positioning demonstrates how this innovation is different from the competitors.					
3.11	Product trials and sales (6)	The price of the whole product is consistent with the target customer's budget.					

3.12	Innovation management (8)	Market relations are built with all the key members of a high-tech marketplace (i.e., customers, press, and analysts, hardware and software partners, distributors, dealers, VARs [value-added-resellers], system integrators, user groups, vertically oriented industry organisations, universities, standards bodies, and international partners).					

TABLE 0-2: Success markers for New Production (1 – totally inapplicable to this project; 3 – partially applicable to this project; 5 – fully applicable to this project)

Nr	Success marker	1	2	3	4	5
1 Initial system design and synthesis according to the specified objectives and constraints						
1.1	The support of the top management is obtained soon after the conceptual idea has been articulated.					
1.2	The system design implies collaborations across organisational boundaries and top managers being involved.					
1.3	A buffer is imbedded in the planning to deal with possible unforeseen challenges.					
1.4	There is the presence of technological skill and know-how within the company, as well as vision and determination within the top management of the company on the benefits of the innovation.					
1.5	Designers have enough freedom to select among different physical implementation alternatives, separating the system's objectives from the means of achievement.					
1.6	Low-level activities and decisions are linked to high-level goals and requirements by assembling multi-competence teams.					
1.7	There is a good understanding of interrelationships among the different elements of a system design, for instance by studying these interrelationships in detail and involving users in an early stage of the design.					
1.8	In small companies, communication on the innovation takes place rather informally within tight knit teams. In large companies or in situations with large user communities, communication happens through speeches, presentations, e-learnings, video tutorials and so on.					
1.9	Development roadmaps are in place, and the objectives are well articulated by the leaders of the innovation and understood by the designers involved. However, trial and error can also play an important role.					
2 Modelling, analysis and simulation						
2.1	User testing, pilot testing, running simulations in experimental set ups, and prototyping the design are performed.					
2.2	Users and operating personnel are involved to improve the quality of test results and the adoption of the process.					
2.2	Additional investments are made in time, tools and knowledge.					
2.3	Information is collected on the system layout and operating procedures based on conversations with the experts for each part of the system.					
2.4	Interaction with managers happens on a regular basis to make sure that the correct problem is being solved and to increase model credibility.					
3 Final design and implementation						
3.1	Training is offered to the users on how to enjoy the benefits of the new process. Users learn and develop competence in using the innovation, use those competencies in the manufacturing process, and continue using the innovation willingly.					
3.2	The innovation offers a holistic approach and allows for full integration with existing processes.					
3.3	Companies align their new production systems with customer and supplier relationships.					

Nr	Success marker	1	2	3	4	5
4 Redesign and reconfiguration						
4.1	Continuous or repeated periodical redesign and reconfiguration efforts, both on physical and on logical aspects take place.					
4.2	User feedback is constantly collected and the innovative technology is customised to the user needs, redesigning the process along newly formulated requirements.					
4.3	The innovation allows for high degree of flexibility and reconfiguration in case of changing demands.					

1. Context and objectives of the study

The current report represents the Final Report for Lot 2 of the study on "Open innovation and enabling technologies: analysis of conditions for transfer of knowledge" (service contract nr NMP1-SC-2011-IN0002) carried out by PwC for DG RTD of the European Commission.

This chapter aims to provide the reader with the background information on the context and objectives of the study, definitions and scope, as well as the types of analysed innovations. In the end of this chapter, we also present the structure of the report.

1.1. Context of the study

Key Enabling Technologies (hereafter "KETs") are considered to be essential for enhancing European global competitiveness, and help solve grand societal challenges in the fields such as energy, climate change, healthcare, security, etc. KETs enable process, goods and service innovation throughout the economy. These technologies are knowledge-intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment. They are multidisciplinary, cutting across multiple technology areas with a trend towards convergence and integration. KETs have a high economic potential and are considered to be the driving force of the new goods and services that will determine the market in the next 10-20 years. Facilitating the development of such technologies is therefore essential to strengthen the industrial and innovation capacity of Europe, to lay stable foundations for creating well-paid jobs and to allow for sustainable, broadly shared growth through managing the shift to a sustainable knowledge-based economy[4].

A wide range of actions at national, EU and international levels are necessary to support the development of KETs, and the Europe 2020 Strategy[5] comprises a number of flagship initiatives to catalyse the progress. One of such flagship initiatives refers to "Innovation Union"[6] supported by a series of strategic documents such as the Final Report on Key Enabling Technologies by the High Level Expert Group (2011)[7], the Communication on "A European strategy for Key Enabling Technologies – A bridge to growth and jobs" (COM(2012) 341), and the Industrial Policy

[4] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: "Preparing for our future: Developing a common strategy for key enabling technologies in the EU", COM(2009) 512 final, Brussels, 30.09.2009.
[5] http://ec.europa.eu/europe2020/index_en.htm
[6] http://ec.europa.eu/research/innovation-union/index_en.cfm
[7] http://ec.europa.eu/enterprise/sectors/ict/files/kets/hlg_report_final_en.pdf

Communication "A Stronger European Industry for Growth and Economic Recovery" (COM(2012) 582).

A key objective of the Innovation Union is to establish the right framework conditions in the EU for turning promising ideas into products and services that are successful on the market. In other words, the Innovation Union aims to boost the whole innovation chain, from research to retail, by combining world-class science and research with an innovation economy, removing bottlenecks that hamper a single market in innovation and which prevent Europe from competing as it should with the rest of the world, and by bringing together the main actors in key areas and aiming to strike the right balance between collaboration and competition. It requires enhancing access to finance for innovative companies, creating a single innovation market, promoting openness and capitalising on Europe's creative potential. It also requires finding ways of bridging the gap that exists between the outputs of R&D projects and innovation/commercial production.

The phase between research outputs and actual innovation/commercial production is commonly referred to as the "valley of death". Countless potentially valuable ideas have 'died' and continue to 'die' during this phase, for a number of reasons that, among others, include:

- an insufficient or insufficiently consistent quality of research;
- a poor interaction between university and industry, hampering innovation and collaboration;
- low mobility of researchers and engineers between industry and academia;
- scarce financing for early- or mid-stage technology companies;
- high Intellectual Property protection costs;
- weak and dispersed innovation clusters;
- market fragmentation;
- insufficient entrepreneurship skills etc.

The "valley of death" exists in the innovation cycle everywhere in the world, not only in the EU. However, for a number of reasons, the EU's valley is often reported to be wider and more difficult to cross than valleys of some other nations and regions (e.g., North America and East Asia). ***Achieving the objectives of the Innovation Union initiative and closing the innovation gap with the EU's competitors requires finding ways to reduce the length of the EU's "valley of death" and to better support those who undertake to cross it***.

From that perspective, ***the current study aims to provide information concerning the factors that determine the chance of survival of the innovation in the "valley of death", as well as the elements that can help to cross the valley as quickly and safely as possible and to become commercially successful on the market***. These factors and

The EU has a clear need for information on the factors that determine the chance of survival of the innovation in the "valley of death", as well as the elements that can help to cross the valley as quickly and safely as possible and to become commercially successful on the market.

elements are numerous and complex, and relate to different steps of the innovation cycle, e.g., exploration, prototyping, first test products, demonstration, business plan, marketing during which a project can encounter obstacles, etc. By doing so, the study aims to enhance our understanding of how an innovation needs to be supported to successfully pass through the entire cycle and reach its final users. The study aims to help identify trends and patterns that prove valuable for designing future research and innovation policies.

1.2. Objectives of the study

The overall objective of the study is ***to analyse the pathway from research activities to the market through a series of innovation cases, with a view to identify how to bridge the gap between the outputs of research activities and successful innovation***.

To this end, the study implies two parallel and complementary approaches corresponding to two separate lots:

- On the basis of ***a sample of EU-funded research projects***, the study aims to analyse the precise and practical steps followed from the completion of research projects to the dissemination/exploitation of the results generated by such research work, leading or not to the market, as well as the obstacles met and overcome or not. The objective is to detect the factors explaining the success or failure of innovation and market access based on outputs of research activities, and to propose recommendations to facilitate the transition from research to innovation and market. This is the subject of *Lot 1* of the study.

- On the basis of ***a sample of commercially successful innovations in Europe and beyond***, the study aims to identify and analyse the upstream research and other activities which contributed to the success of those innovations. The objective is to identify ex-post the specific features of the research work which produced the relevant knowledge and know-how used by innovation-induced commercial successes in the field of industrial technologies, as well as the dissemination and exploitation pathways and the critical steps which have led to the effective (and progressive) take up by industry (large corporations, as well as small companies). This "reverse engineering" approach aims to help better understand the role of R&D, as well as of other key factors in leading to successful innovations. This is the subject of *Lot 2* of the study.

The objective of two Lots is to jointly provide enhanced knowledge on ways and conditions to transfer knowledge from research projects to industrial innovators and to the market, based on practical experience and fieldwork. The current report exclusively refers to Lot 2 of the study.

Lot 2 focuses on a longitudinal and field analysis of a sample of commercially successful innovations in order to detect:

- The traceability of the process from the introduction of those innovations up to their technical source(s) or origin(s), their successive steps, their diffusion time and pattern, etc.;
- The factors explaining or easing the implementation and success of such technological innovations;
- Obstacles that have been encountered during the diffusion and implementation phase after completion of work at research/technology level, and how those have been overcome;
- Channels of dissemination of technical information that have proved effective or possibly less effective.

The study aims to shed light on the question of how to best fund research projects in the NMP area to improve results in terms of exploitation.

The current study fits well into a wide range of the innovation-related initiatives of DG RTD. It is expected ***to help the Commission understand how to increase the innovation output in the Seventh Framework Programme project cycle and in the future Horizon 2020 Programme***, and in particular, how to (1) foster innovation at all the stages of the project cycle, (2) expand the exploitation side of projects (closer to market take up), and (3) improve the entrepreneurial strategies and capacities of partners in FP7/future H2020 projects. The study aims to shed light on the question of how to best fund research projects in the NMP[8] area to improve results in terms of exploitation.

Two key tasks of the Lot 2 of the study can therefore be formulated as follows:

(1) Based on the analysis of best practices, to provide the Commission as a public funder with a set of specific recommendations on the process improvement for FP7- and future H2020-related actions. The latter refer to drafting calls for proposals, setting expectations, developing evaluation criteria, assessing, selecting and monitoring projects. The recommendations should aim at helping the Commission to

[8] Nanosciences, Nanotechnologies, Materials and New Production Technologies

increase the effectiveness of FP7- and H2020-funded NMP projects.

(2) To propose operational recommendations to Project Partners (e.g., entrepreneurs, research centres) on the ways and conditions to transfer knowledge from research projects to the market, as well as on how to ensure the marketability of innovations.

Two key outcomes of Lot 2 include:

- *Case studies* providing a clear description of the process from research outcomes to exploitation, including key steps, development of factors, role of actors, how to handle obstacles etc.
- *Synthesis* providing answers to the Commission as a public funder, and to Project Partners.

1.3. Scope of the study

Lot 2 of the study focuses on commercially successful innovations in the fields of nanotechnology, micro- and nanoelectronics, photonics, advanced materials and advanced manufacturing.

The current study focuses on NMP innovations or innovations covering Nanosciences, Nanotechnologies, Materials and New Production Technologies. NMP constitute one of the ten thematic priorities of the "Cooperation" programme, one of the seven specific programmes that compose the EU's Seventh Framework Programme for Research and Technological Development. The core objective of the NMP theme is to improve the competitiveness of European industry and to generate the knowledge needed to transform it from a resource-intensive to a knowledge-intensive industry. NMP research also aims to strengthen the competitiveness of European industry by generating 'step changes' in a wide range of sectors and implementing decisive knowledge for new applications between different technologies and disciplines. NMP overlap with most of the KETs.

1.3.1. Key definitions

Lot 2 focuses on the following KETs: nanotechnology; micro- and nanoelectronics; photonics; advanced materials (e.g., advanced metals, advanced synthetic polymers, advanced ceramics, novel composites, advanced bio-based polymers); *and* advanced manufacturing. Below we elaborate on the definitions for each of the abovementioned KETs.

Nanotechnologies

Nanotechnology broadly refers to fields such as physics, chemistry, biology, biotechnology, material sciences or a combination thereof, that deals with the deliberate and controlled manufacturing of nanostructures. Nanotechnology is not an industry, nor is it a single technology or a single field of research. It consists of sets of enabling technologies applicable to many traditional industries. Therefore it is more appropriate to speak of nanotechnologies in the plural. Nanotechnologies are often described as *platform technology* – these are technologies that serve as springboards for other technologies and as foundations for many diverse applications; these technologies are also regarded as essential for progress in multiple fields.

There is no universal definition of nanotechnology. Most definitions today revolve around the study and control of phenomena and materials at length scales below 100 nm. Some definitions include a reference to molecular systems and devices.

Nanotechnology is highly diverse, ranging from extensions of conventional device physics to completely new approaches based upon molecular self-assembly, from developing new materials with dimensions on the nanoscale to investigating whether we can directly control matter on the atomic scale[9].

Most current nanotechnology applications are limited to the use of "first generation"[10] passive nanomaterials which include titanium dioxide in sunscreen, cosmetics, surface coatings, and some food products; carbon allotropes used to produce gecko tape; silver in food packaging, clothing, disinfectants and household appliances; zinc oxide in sunscreens and cosmetics, surface coatings, paints and outdoor furniture varnishes; and cerium oxide as a fuel catalyst.

Micro- and nanoelectronics

The micro- and nanoelectronics industry can be defined as having two distinct sub-categories. These are broken down as 'More Moore' and 'More than Moore'. The 'More Moore' industry segment is defined by its focus on the continued shrinking of physical feature sizes of the digital functionalities (logic and memory storage) in order to improve density (cost per function reduction) and performance (speed, power), and decreasing costs (increased yields, bigger wafers). This More-Moore

[9] http://en.wikipedia.org/wiki/Nanotechnology

[10] Bowman D. (2007) Patently obvious: Intellectual property rights and nanotechnology. Technology in Society 29 (2007), pp. 307-315

technology accounts for a large share of the global semiconductor market[11].

The ‘More-than-Moore’ industry segment, in turn, refers to the incorporation into devices of functionalities that do not necessarily scale according to ‘Moore Law’, but provide additional value in different ways. The ‘More-than-Moore’ approach allows for a greater variety of semiconductor devices to be combined on the same chip in so-called SoCs (System-on-chip) or in the same package using so-called SiPs (System-in-Package). This concept involves many other devices on top of the pure miniaturisation (CMOS) process, such as analog/radio frequency, passives, high voltage power, sensors, biochips and MEMS (Micro-Electro-Mechanical systems) components. These devices are processed and embedded in the chip/package instead of being added at systems level. This improves system integration and opens new application fields. Interacting with people and the environment and powering the system are the main elements of More-than-Moore[12].

Photonics

Photonics is a multidisciplinary domain dealing with light, encompassing its generation, detection and management. Among others, it provides the technological basis for the economical conversion of sunlight to electricity which is important for the production of renewable energy, and a variety of electronic components and equipment such as photodiodes, LEDs and lasers[13]. Examples of photonics applications are barcode scanners, optical fiber, CD/DVD/Blu-ray devices, remote control devices, IR sensors, printed circuit boards, tools for laser surgery etc.

Advanced materials

Advanced or new materials are materials that provide properties that may not be readily available in nature, materials that gain their properties from structure rather than composition, using the inclusion of small inhomogeneities to enact effective macroscopic behaviour resulting in changes in novel characteristics such as, for example, a negative refractive index, electrical properties, strength etc. Additionally, new materials can be tailored to specific requirements (e.g., graded seals). New materials encompass a wide range of materials from composites with high strength/weight ratios to silicon wafers with feature sizes

[11] Interim Thematic Report by the Micro/Nanoelectronics Sherpa Team, part of the High Level Group on KETs, November 2010

[12] Interim Thematic Report by the Micro/Nanoelectronics Sherpa Team, part of the High Level Group on KETs, November 2010

[13] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: "Preparing for our future: Developing a common strategy for key enabling technologies in the EU", COM(2009) 512 final, Brussels, 30.09.2009.

approaching atomic dimensions[14]. Examples of advanced materials include advanced metals, advanced synthetic polymers, advanced ceramics, novel composites, and advanced bio-based polymers.

Advanced manufacturing

Advanced Manufacturing comprises production systems and associated services, processes, plants and equipment, including automation, robotics, measurement systems, cognitive information processing, signal processing and production control by high-speed information and communication systems. Advanced manufacturing is essential for productivity gains across sectors such as the aerospace, automotive, consumer products, electronics, engineering, energy-intensive, food and agricultural as well as optical industries. It also can make an effective response to societal challenges including health, climate change, resource efficiency and job creation. The advanced manufacturing definition here covers both manufacturing of high-tech products, processes and solutions for future manufacturing, as well as services associated with them[15].

1.3.2. Geographical scope

In geographical terms, the scope of Lot 2 is not limited to the EU, but is of ***global orientation***. One of the tasks of Lot 2 is to identify and analyse the possible differences in trajectories of successful innovations that could be due to the specificities of socio-economic environments, including cultural specificities. This requires analysing success stories beyond Europe's borders, in particular in nations and regions that are generally recognised for their innovation capacities (in particular North America and East Asia). The scope of the analysis is therefore not limited to innovation-induced market successes resulting from research activities carried out in the EU, in particular from EU-funded NMP research projects. The selection of cases was based on the combination of the technical interest of the concerned innovation and of its recognised success on the market, its geographical location and the sources of funding. A detailed description of the methodology is provided in the next chapter.

1.3.3. Types of cases

Lot 2 focuses on three types of innovation cases:

- ***Type I New Products***: *intermediates* (e.g., coatings, fabrics, memory and logic chips, contrast media, optical components, superconducting wire etc.) and *end-user products* (e.g., cars, clothing, airplanes, computers, consumer electronics devices, plastic

[14] Commission on Engineering and Technical Systems and National Research Council, 1993
[15] Thematic report by the Working Team on Advanced Manufacturing Systems, 2010

containers, appliances etc.) whose performance is determined by nanotechnology, micro- and nanoelectronics and/or photonics;

- ***Type II New Materials***: materials that provide properties that may not be readily available in nature; materials that gain their properties from structure rather than composition, using certain adjustments to enact effective macroscopic behavior resulting in changes in novel characteristics (e.g., advanced metals, advanced synthetic polymers, advanced ceramics, novel composites, advanced bio-based polymers); *and*

- ***Type III New Production***: continuous innovations (industrial activities and production systems, including design, infrastructure, equipment, and services) and the development of generic production 'assets' combining technologies, organisation, production facilities and human resources, while also meeting overall industrial safety and environmental requirements. This category includes sub-groups such as the development and validation of new industrial models and strategies (e.g., mass customisation, open design and open innovation manufacturing, cloud production, sustainable manufacturing); adaptive production systems and networked production.

Our empirical analysis indicated significant similarities between the progression of innovations within the first two categories, while the third category proves to follow a completely different trajectory. Therefore, any generalisations of conclusions to the whole category of NMP innovations should be made with great caution.

1.4. Report structure

The remainder of this report is organised as follows. *Chapter 2* presents the key elements of the methodology including sample selection, the organisation of fieldwork, approach to data analysis, as well as key challenges and solutions. *Chapter 3* contains the key study findings and offers answers to the key analytical questions. *Chapter 4* includes detailed recommendations on how to best fund research projects in the NMP area to improve results in terms of exploitation. Finally, *Annex A* offers concise case study descriptions of all analysed innovations.

2. *Methodology*

The current chapter presents the key aspects of the employed methodology. We specifically elaborate on the study design, identification and selection of cases, fieldwork activities, data analysis and synthesis, as well as key challenges and solutions.

2.1. Study design

To achieve the objectives of Lot 2 presented in the previous chapter, we followed ***a multi-dimensional approach based on a synergetic mix of methods, perspectives and tools***. The study involved six consequent technical phases and one continuous project and risk management track. The objective of the six technical phases was to extract evidence-based policy recommendations from the ***reverse engineering analysis***[16]. The project and risk management track aimed to ensure effective, efficient and flawless execution of project activities within the six technical project phases. Although the research usually represents a non-linear process and is of iterative nature, we employ a linear visualisation of the main phases (see Figure 2-1), as this approach allows for keeping better track of the milestones and for monitoring of the progress of deliverables.

[16] By spanning the innovation lifecycle stages, reverse engineering covers a broad range of factors starting from a success on the market and going back to the technical sources or origins of a certain technological innovation. Reverse engineering can be performed starting from any level of abstraction or at any stage of the innovation cycle. It is a process of *examination*, and not a process of change or replication. In the context of the current study, reverse engineering implied recovering knowledge about *how* and *why* certain key technological innovations in the NMP field got accepted by industry and/or became successful on the market.

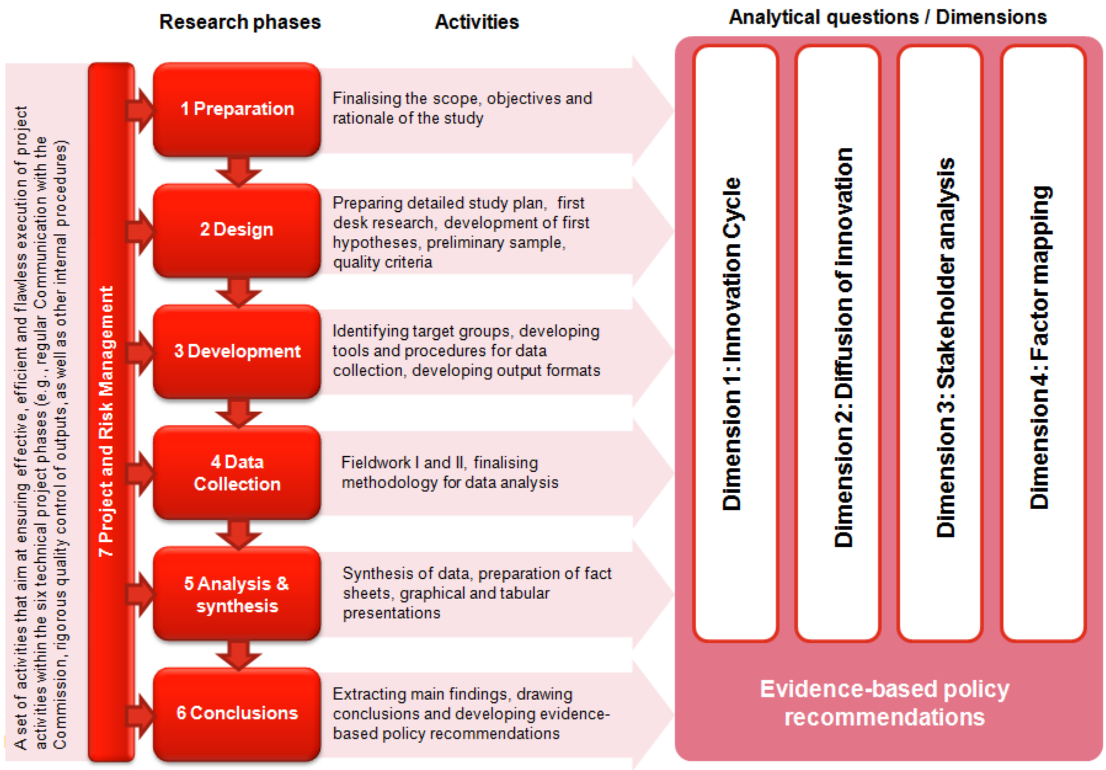

FIGURE 2-1: Study design

2.1.1. *Reverse engineering algorithm*

Analysing data using a reverse engineering algorithm in its essence consists of three basic steps: Identify, Collect and Integrate (ICI model). Figure 2-2 presents the process and the relationships among its parts. As illustrated by the Figure, this process is not linear. Rather, the process has the following distinctive characteristics:

- *Iterative and progressive*: the process represents a cycle that keeps repeating;
- *Recursive*: one part can call the research team back to the previous part (for example, while we were collecting data, we simultaneously started identifying new data to be collected);
- *Holographic*: each step of the process contains the entire process.

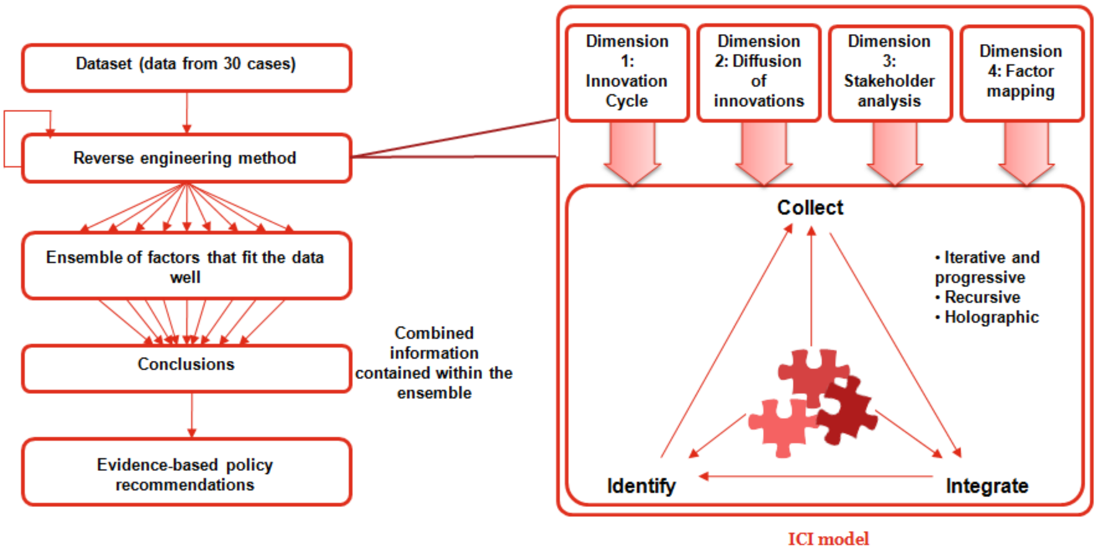

FIGURE 2-2: Reverse engineering algorithm

2.1.2. *Multi-dimensional approach*

The selected sample of successful innovations was analysed from the perspective of the following four dimensions:

(1) Innovation cycle;
(2) Diffusion of innovations;
(3) Stakeholder analysis;
(4) Factor mapping.

Dimension 1: Innovation cycle is a framework for understanding the progression of innovation over time, from research to access to the market and its consequent development on the market. The framework allows for mapping important decision points and milestones, and linking the development of an innovation to a time scale. While the innovation cycle framework is broadly generalised and does not reflect the course of development of all NMP innovations, it is a useful model for tracing and understanding various stages of creation and utilisation of innovations.

Dimension 2: Diffusion of innovations refers to a framework allowing to explain how and why new ideas and technologies spread through the community. Employing the diffusion of innovations theory in the context of this study allowed analysing diffusion time and diffusion pattern of innovations, including various channels of dissemination of technical information, to highlight those that have proved to be effective and those that have possibly been less effective.

Dimension 3: Stakeholder analysis is the process of identifying individuals and/or groups that are likely to affect or be affected by a particular innovation, and classifying them according to their impact on the innovation or to the impact the innovation will have on them. The first step of the stakeholder analysis for this study implied building a categorised list of relevant stakeholders (e.g., actors of the market, actors of the value chain, research partners, public actors etc.). Once the list was complete, priorities were assigned according to the estimated level of impact. Stakeholder analysis was used to identify the key stakeholders and their respective impact on the progression of innovations. Combined with the previous two dimensions, factor stakeholder analysis provided an understanding of specific roles and contributions of the participants in the innovation process.

Dimension 4: Factor mapping is the process of visually representing various levels of factors influencing the development of a particular innovation. Factor mapping allows structuring critical enablers, encountered obstacles and corresponding solutions. The respective levels include individual, organisational, cluster, national, European/regional and global layers. Another dimension of factor mapping refers to different types of factors within each level (e.g., formal vs. informal). Using factor mapping techniques for this study allowed to detect the factors that have explained or have eased the implementation and success of technological innovations; as well as to identify the obstacles that have been encountered during the diffusion and implementation phase after completion of the research work and the corresponding solutions.

Such multi-dimensional approach instead of an exclusive focus on one dimension allowed us to adequately reflect the complex nature of NMP innovations by analysing their development from multiple complementary perspectives.

2.1.3. Key activities

The study implied three specific types of activities:

(1) *Desk research* to identify innovative products, processes or materials in the field of NMP to establish a sample, provide methodology and preliminary fact-sheets;

(2) *Fieldwork* to obtain the key data from the stakeholders;

(3) *Synthesis* of data to provide an analytical view on highlighted aspects, policy options and practical guide to manage the exploitation cycle.

Below we elaborate on each of the activities in more detail.

The study began with a comprehensive desk research including the relevant academic literature, commercial publications, search within databases and other dedicated web-resources. First desk research results allowed for the development of detailed research questions and hypotheses, as well as for the identification of significant innovative products, processes or materials in the field of NMP. Based on these findings, the initial sample of about 50 relevant cases was developed in order to later reduce it till 30 cases to be analysed through the fieldwork. The selection process focused on cases that combined the technical interest of the innovation, its recognised success on the market, as well as geographical coverage. The selected innovations were preferably not related to projects financed by the EU programmes. Then the preliminary fact sheet for each case of the sample was prepared based on the available information.

The fieldwork consisted of several steps including desk-research and exploratory interviews followed by a series of in-depth interviews. The key challenge was to identify the focal persons within each case and make sure they act as ambassadors of the study towards other relevant stakeholders. The fieldwork was carried out in two consequent rounds (first, Fieldwork I: 12 cases, and then Fieldwork II: 18 cases). Such consecutive approach allowed for effective use of professionals with the relevant expertise, as well as for rigorous quality control and for keeping good track of all the information flows.

During the fieldwork, the obtained data was entered into a structured data collection system (case study database). This system enabled the project team to have a real-time overview of the empirical progress made within each of the 30 cases. The data collection system was built around the four dimensions relevant for the analysis. The final part of the study focused on the synthesis of the collected data, the preparation of detailed case study descriptions and the extraction of the evidence-based policy recommendations.

Below we elaborate on each of those activities in more detail.

2.2. Identification and selection of cases

The conclusions and recommendations of Lot 2 are based on a detailed analysis of 30 NMP innovation cases. Therefore, for the success of the study, it was crucial to develop reliable and objective procedures for the identification and selection of cases, and to ensure that the selected cases offer a good representation of diverse sectors and types of NMP innovations (i.e., materials, products, new production), as well as geographical regions. Below we present the key aspects of those procedures.

2.2.1. Identification of cases

The initial identification of cases was performed based on a comprehensive desk research. A wide range of credible sources has been reviewed including publications in prominent academic journals, business and policy reports, commercial publications and newsletters, product databases and other dedicated web resources. In addition, we have mobilised our extensive industrial networks and our External Expert Committee (five world-class experts in the field of NMP innovation) to provide us with the indication of potential cases based on their awareness of the key innovations in the field. When searching for the potential cases on the Internet, we were particularly looking for the ones referenced to by others as NMP innovation showcases.

Specifically, the following types of search were conducted for the identification of potential cases:

- Search within publications in prominent academic journals by means of *scholar.google.com* engine
    - Examples of journals relevant for new products: *"International Journal of Humanoid Robotics", "IEEE Photonics Journal"*, *"Microelectronics Journal", "Journal of Nanotechnology, Science and Applications", "Journal of Product Innovation Management"*;
    - Examples of journals relevant for new production: *"International Journal of Production Research"; "Advances in Production Engineering & Management"*;
    - Examples of journals relevant for new materials: *"Advanced Materials", "Advanced Composite Materials", "Advanced Functional Materials", "JOM", "Journal of Electronic Materials", "Light Metal Age", "Materials Today", "Nature Material", "Science and Technology of Advanced Materials"*.
- Search within business and policy reports, commercial publications and newsletters:
    - *Mass customization and open innovation news* - notes and ideas on mass customisation, personalisation, customer co-creation, and open innovation - strategies of value co-creation between organisations and customers. This blog continues a long running newsletter, published and edited by Frank Piller, RWTH / MIT, since 1997 http://mass-customization.blogs.com/mass_customization_open_i/2010/10/from-open-innovation-to-open-manufacturing-m-tseng-on-shanzhai-cell-phones-in-china-a-model-of-open-.html;
    - *The Robot Report blog*: the blog tracks the business of robotics and provides a free database of links to robotics companies and educational facilities worldwide (http://www.therobotreport.com/).

- Search within dedicated databases that list large numbers of specific products containing nanomaterials[17]:
  - *The Project on Emerging Nanotechnologies* (based on a partnership between the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts), which is currently the most comprehensive online resource for nanomaterials in consumer articles. The resource entails several on-line databases (http://www.nanotechproject.org/inventories/) including the "inventory of nanotechnology-based consumer products currently on the market" which lists more than 1000 consumer products and is widely used in other studies (such as Afsset (2006)[18]);
  - *The Nanomaterials Database from Nanowerk*, which clearly demonstrates the current availability of nanomaterials. This online searchable resource provides links to over 2000 commercially available nanomaterials (from nearly 150 suppliers; http://www.nanowerk.com/phpscripts/n_dbsearch.php);
  - *The A to Z of Nanotechnology*, another extensive online resource including directories not only by material but also by suppliers, applications and industry. The directory (http://www.azonano.com/materials.asp) lists over 1300 nanomaterials;
  - The US EPA's *Nanoscale Materials Stewardship Program*, which has led 29 companies and trade associations to submit information (often limited and/or confidential) on 123 nanomaterials (based on 58 chemicals) of which less than half are 'commercial'. (http://www.epa.gov/opptintr/nano/stewardship.htm)
  - *The Oklahoma Nanotech Initiative*, which is not as extensive but provides an instructive overview of the range of products (http://www.oknano.com/pdf/ NanoProductsShowroom.pdf) available to the ordinary US consumer; and
  - *The listing of 100 consumer products presented by the European consumer bodies (ANEC/BEUC)* in their recent (June 2009) position paper "Nanotechnology: Small is beautiful but is it safe?" (http://www.anec.org/attachments/ANEC-PT-2009-Nano-002final.pdf)

17 "Information from Industry on Applied Nanomaterials and their Safety", Deliverable I, prepared for EU DG Environment, September 2009

18 Afsset (2006): Les Nanomateriaux: Effets sur la Santé de l'Homme et sur l'Environnement, report of French expert group, dated July 2006

- General Internet search via google.com engine using specific key words:
  - Examples of key words for new products: "nanotechnology new product", "nanotechnology commercial success", "nanotechnology innovation", "microelectronics new product", "microelectronics commercial success", "microelectronics innovation", "nanoelectronics new product", "nanoelectronics commercial success", "nanoelectronics innovation", "photonics new product", "photonics commercial success", "photonics innovation";
  - Examples of key words for new materials: "advanced metals", "new metals", "advanced synthetic polymers", "new synthetic polymers", "advanced ceramics", "new ceramics", "novel composites", "advanced bio-based polymers", "advanced materials commercial success", "new materials commercial success";
  - Examples of key words for new production: "sustainable manufacturing", "mass customisation", "open innovation manufacturing", "cloud manufacturing", "adaptive production systems", "new production", "e-production", "networked production".

Given an important role of issues such as the availability of information and the willingness of stakeholders to participate in the study, there was a clear need for flexibility with regard to the final sample. In the course of the fieldwork, some cases needed to be replaced by other cases, and new relevant cases were discovered.

As a result of this exercise, more than 100 potentially relevant cases were identified, and the next step implied screening and pre-selection of cases for the preliminary sample of 50 cases.

2.2.2. Selection of cases

The selection process aimed to spot the cases that combine the following three elements:

(1) technical interest of the innovation,
(2) recognised success of the innovation on the market, *and*
(3) geographical coverage.

The preference was given to innovations not explicitly financed by the EU programmes as those fall under the scope of Lot 1. Below we elaborate on each of the abovementioned criteria in more detail. Each criterion is tailored to the specifics of each of the three NMP types (New Products, New Materials and New Production).

Criterion 1: Technical interest of the innovation

Products were considered technically interesting if they:

- represent a combination of innovative materials, successful design and intelligent functionalities.

Materials were considered technically interesting if they:

- efficiently encompass phenomena and architectures at the atomic scale and/or are able to optimise their engineered properties at higher length scales and in properties of the final products.

Production processes were considered technically interesting if they:

- create the appropriate conditions for continuous innovation (in industrial activities and production systems, including design, infrastructure, equipment, and services);
- create the appropriate conditions for developing generic production 'assets' (technologies, organisation, production facilities and human resources).

The judgement of the project team on whether a potential case satisfies this criterion or not was made based on the screening of the information about a particular case on a dedicated website. This screening was also accompanied by examining the information from the referencing websites (websites referring to a case as a showcase). Cases included in the preliminary sample exclusively referred to the ones that satisfy the criterion in question based on the abovementioned judgement.

Criterion 2: Successful implementation by industry or recognised success on the market

Products were considered as having success on the market is they:

- have been rapidly transferred from research into products; *and*
- have been released onto the market.

Materials were considered as having success on the market if they:

- are actively used in intermediates and/or end-user products.

Production processes were considered successfully implemented by industry if they:

- refer to new manufacturing and business models covering all aspects of product and process life-cycle, including but not limited to a full risk assessment at each critical stage of the life cycle; *and/or*

- imply the integration of reconfigurable technical systems and processes with factory level systems; *and/or*
- imply integration of technical intelligence from sensors and actuators; *and/or*
- refer to efficient systems networks based on standards.

Similar to the previous criterion, the judgement of the project team on whether a potential case satisfies the second criterion or not was made based on the screening of the information about a particular case on a dedicated website. This screening was also accompanied by examining the information from the referencing websites (websites referring to a case as a showcase). Cases included in the preliminary sample exclusively refer to the ones that satisfy the criterion in question based on the abovementioned judgement. Consequently, if cases were included in the preliminary sample, they had been successfully introduced to the market/implemented in practice.

Criterion 3: Geographical coverage

The leading NMP regions include North America, Europe and East Asia. For the purpose of the current study, we drew a geographically well-balanced sample and included products, materials and production processes from each of the abovementioned regions. Given that the EU represents the primary focus of the study, we selected 21 case from this region. The rest (9 cases) were divided between North America and East Asia. By East Asia here one should understand China, Japan, South Korea, Singapore, and Taiwan.

During the search activities, we have also spotted several unique showcases from countries that originally do not fall under the scope of this study (e.g., Israel, Turkey, India, Australia). Nevertheless, given their extraordinary nature, we have included them in the preliminary sample as extra potential cases for consideration.

2.2.3. Final composition of sample

Following the steps described above, a preliminary sample of about 50 cases was developed. The final selection of 30 cases was made in close consultation with the Commission, based on the criteria such as the availability of data and the willingness of the relevant stakeholders to cooperate. Tables 2-1 and 2-3 present a general distribution of cases among various types and regions for Fieldwork I and II respectively, while Tables 2-2 and 2-4 provide an overview of specific cases selected for each of the two fieldwork rounds. Table 2-5 presents the total distribution of cases (10 cases for New products, 10 cases for New materials, and 10 cases for New production).

TABLE 2-1: Distribution of cases in Fieldwork I

Case types ->	Type I New products		Type II New materials	Type III New production			
Regions:	*Nanotechnology, micro- and nanoelectronics, photonics*		*Advanced metals, advanced synthetic polymers, advanced ceramics, novel composites, advanced bio-based polymers*	*Advanced manufacturing systems, processes, models, strategies*			
	I.1 Intermediates	I.2 End-products		III.1 New industrial models and strategies	III.2 Adaptive production systems	III.3 Networked production	TOTAL:
Europe	0	2	3	0	0	0	**5**
East Asia	1	1	1	0	0	1	**4**
North America	0	1	0	2	0	0	**3**
TOTAL sub-groups:	**1**	**4**	**4**	**2**	**0**	**1**	**12**
TOTAL:	**5**		**4**	**3**			**12**

TABLE 2-2: Overview of cases for Fieldwork I

Fieldwork I ***Name***	***Region***	***Country***
I.1 New products: Intermediates (1)		
(1) I.1.B.2 Ultra Compact Femtosecond Fiber Laser PFL-200	East Asia	Japan
I.2 New products: End products (4)		
(2) I.2.A.6 Q.E.F. Electronic Innovations Epilepsy Bracelet	Europe	Netherlands
(3) I.2.A.7 NAO robotics research platform	Europe	France
(4) I.2.B.3 APADENT and APAGARD Nanohydroxyapatite Toothpaste	East Asia	Japan
(5) I.2.C.1 Silverlon Wound Care and Surgical dressings	North America	United States
II New materials (4)		
(6) II.A.4 Oerlikon diamond coatings	Europe	Luxembourg
(7) II.A.8 Crystalsol flexible photovoltaic technology	Europe	Austria
(8) II.A.7 Technically Hybrix™ sandwich material	Europe	Sweden
(9) II.B.1 Glow in the dark powder	East Asia	Taiwan
III New Production: New Industrial Models and Strategies (2)		
(10) III.1.C.1 Local Motors	North America	United States

Fieldwork I		
crowdsourced car manufacturing		
(11) III.1.C.2 MakerBot 3D printer crowdsourced manufacturing	North America	United States
III New Production: Networked Production (1)		
(12) III.3.A.1 Ponoko's user manufacturing platform	East Asia/Pacific	New Zealand

TABLE 2-3: Distribution of cases in Fieldwork II

Case types ->	**Type I New products**		**Type II New materials**	**Type III New production**			
Regions:	*Nanotechnology, micro- and nanoelectronics, photonics*		*Advanced metals, advanced synthetic polymers, advanced ceramics, novel composites, advanced bio-based polymers*	*Advanced manufacturing systems, processes, models, strategies*			
	I.1 Intermediates	I.2 End-products		III.1 New industrial models and strategies	III.2 Adaptive production systems	III.3 Networked production	**TOTAL:**
Europe	4	1	5	3	2	1	**16**
East Asia	0	0	0	0	1	0	**1**
North America	0	0	1	0	0	0	**1**
TOTAL sub-groups:	**4**	**1**	**6**	**3**	**3**	**1**	**18**
TOTAL:	**5**		**6**	**7**			**18**

TABLE 2-4: Overview of cases for Fieldwork II

Fieldwork II ***Name***	***Region***	***Country***
I.1 Intermediates (4)		
(1)FII.I.1.1 DFB laser	Europe	Germany
(2) FII.I.1.2 Envirox™	Europe	United Kingdom
(3) FII.I.1.3 Advanced Marine Coatings	Europe	Norway
(4) FII.I.1.4 Triple O Performance Solution	Europe	United Kingdom
I.2 End products (1)		
(5) FII.I.2.1 T-Sight 5000	Europe	Italy
II New Materials (6)		
(6) FII.II.1 NKR® single crystal alumina fibers	Europe	Spain
(7) FII.II.2 Kriya Materials B.V.	Europe	The Netherlands
(8) FII.II.3 SA Envitech s.r.l.	Europe	Czech Republic

Fieldwork II ***Name***	***Region***	***Country***
(9) FII.II.4 It4ip	Europe	Belgium
(10) FII.II.5 Régéfilms Sud Ouest	Europe	France
(11) FII.II.6 Poss®	North America	United States
III New Production: New Industrial Models and Strategies (3)		
(12) FII.III.1.1 Rhodia, recycling rare earth material from luminescent powders	Europe	France
(13) FII.III.1.2 Nulife Glass, separation and extraction of lead from CRT waste	Europe	United Kingdom
(14) FII.III.1.3 GBL - Fermentation Process	Europe	United Kingdom
III New Production: Adaptive Production Systems (3)		
(15) FII.III.2.1 DyeCoo's liquid CO2 textile dying process	Europe	The Netherlands
(16) FII.III.2.2 Resteel	Europe	The Netherlands
(17) FII.III.2.3 Ricoh's cart production line	East Asia	Japan
III New Production: Networked Production (1)		
(18) FII.III.3.1 Liquisort, magnetic density separation (MDS)	Europe	The Netherlands

TABLE 2-5: Total distribution of cases

Case types ->	**Type I New products**		**Type II New materials**	**Type III New production**			
Regions:	*Nanotechnology, micro- and nanoelectronics, photonics*		*Advanced metals, advanced synthetic polymers, advanced ceramics, novel composites, advanced bio-based polymers*	*Advanced manufacturing systems, processes, models, strategies*			
	I.1 Intermediates	I.2 End-products		III.1 New industrial models and strategies	III.2 Adaptive production systems	III.3 Networked production	**TOTAL:**
Europe	4	3	8	3	2	1	**21**
East Asia	1	1	1	0	1	1	**5**
North America	0	1	1	2	0	0	**4**
TOTAL sub-groups:	**5**	**5**	**10**	**5**	**3**	**2**	**30**
TOTAL:	**10**		**10**	**10**			**30**

2.3. Fieldwork activities

In this sub-section, we elaborate on the key procedures of Fieldwork I and II. Those include approaching the key stakeholders, scheduling interviews, structuring interviews, preparing and validating interview transcripts, consolidating data and reporting.

2.3.1. Stakeholder engagement

Before arranging interviews, we identified the target population (stakeholders) for each of the selected cases. This exercise implied locating the particular individuals who were likely to have a genuine interest in the study and would be willing to dedicate time and effort to cooperate with the project team. In order to secure their participation, we tried to engage some of these stakeholders in different project stages rather than in the data collection stage only. Consulted stakeholders can often provide crucial insights and feedback at different stages of a study that, when taken on board, result in more rigorous research. For example, stakeholder feedback was particularly important when designing an interview questionnaire. Furthermore, it was important for questions to be empirical, that is, answers had to be based on data rather than values or judgement of individual respondents. After the data have been collected, stakeholders were also invited to comment on the interpretation of findings.

In order to increase the motivation of stakeholders to participate in the study, an accompanying letter from the Commission was used. Additionally, the stakeholders were informed about the opportunity to increase the visibility of their innovations through their participation in the study.

The following main categories of stakeholders were consulted:

- Actors of the market (i.e., key companies of determined segments having implemented the technological innovations studied, e.g., CEOs/Directors, R&D, human resources and marketing managers, heads of project, research etc., and customers if appropriate);
- Actors of the value chain (e.g., suppliers);
- Partners in research projects or managers of research programmes having contributed to the development of an innovation.

2.3.2. Case study protocols

The first step of fieldwork activities was the development of the case study protocol. The protocol included the following sections:

- *An overview of the case study project* - project objectives, case study issues, and presentations about the topic under study;
- *Field procedures* - reminders about procedures, credentials for access to data sources, location of those sources;
- *Case study questions* - the questions that we need to keep in mind during data collection;
- *A guide for the case study report* - the outline and format for the case study report.

Having a detailed well-structured and standardised case study protocol allowed for consistency in the approach towards data collection by multiple project team members and for ensuring comparability of results during the analysis stage.

2.3.3. Interviews

Given the complexity of the research questions, case studies implied obtaining a multi-stakeholder perspective. For this purpose, we conducted two-stage interviews. The first stage implied identifying one key actor of the case, i.e., key person involved in the development of a particular innovation or ***'case ambassador'***. During the ***preliminary interviews*** with those people, we aimed to identify other relevant stakeholders to be contacted during the second stage of exploratory interviews or ***in-depth interviews***. In total, we interviewed up to 6 stakeholders per case. We stopped with interviewing additional stakeholders once it was clear that the amount of new *relevant* data coming from additional stakeholders was not significant anymore.

During the interview process, a so called ***snow-ball principle*** was used. Each conducted interview enlarged a base for discussion for further interviews. As a result, the initial fragments of information were gradually expanded and integrated into an overall picture of the considered case. The sequence in which interviews were conducted followed the logic of who can contribute most at the different stages of our investigation. A graphical reconstruction of the innovation cycle was performed during the interviews (especially the first-stage introductory interviews with the key actors per case), enabling the visualisation of the process and serving as a platform for further discussion. Using a structured IT system, we were able to carefully keep track of the response rate, i.e., the number of people who agreed to be interviewed, interview schedule and next steps per case.

During the interviews, both qualitative and quantitative information was collected. This information includes, among others, the following topics:

- Key characteristics of the innovation;
- Origins of the innovation;
- R&D organisation;

- Innovation Management;
- Sources of information;
- Collaboration during the innovation process;
- Role of public funding & services;
- Intellectual property rights;
- The 'life after' commercialisation;
- Internationalisation;
- Impacts & benefits;
- Problems & challenges.

Below we provide a detailed overview of procedures related to interviews.

Email invitations

Our first contact with key persons for each case occurred by means of an introductory email. Whenever possible, such email was sent to the contact person's direct email address. If this was not possible, we sent an email to a general email address of the respective company, specifically identifying that it is addressed to the relevant contact person. The email was composed with an aim to efficiently communicate the objective of the study and to encourage the potential involvement of the approached person. We also emphasised the opportunities the study offers for the visibility of the innovation on the European level. Additionally, we included the support letter of the European Commission as an attachment to the email.

Follow-up calls to engage key informants

To follow up on the introductory emails, we directly approached the specific contact persons by phone to briefly discuss their involvement in the study and to arrange a preliminary interview. We also used this opportunity to briefly test the extent to which the case fitted our sample, as our understanding up to then was driven by desk research only. In most cases, the contact person responded with enthusiasm, and the first interview was scheduled. In other cases, it proved to be more challenging to convince contact persons to participate in the study, for instance, when the targeted company was in the middle of Mergers & Acquisitions process and could not disclose any information, or when the targeted company had discontinued their involvement in the innovation and had transferred all the rights concerning the innovation to another company. In such situations, after careful consideration, in case there was no option of proceeding with that case, we eliminated it from the sample and replaced it by a similar case of comparable technical nature and geography.

Efficient scheduling across different time zones

We scheduled all interviews as efficiently as possible, deploying the project team in a flexible manner, ensuring that the respondents have an interview within their office hours also when in different time zones. We extensively tracked the interview scheduling process in order to have interviews scheduled as quickly as possible, with interviews being conducted by a researcher that is most knowledgeable of the case. Preliminary interviews were scheduled to last 30 minutes. In-depth interviews took on average 60-90 minutes.

Preliminary interviews with 'case ambassadors'

The preliminary interviews were conducted with an objective to increase our basic knowledge of the case, to determine the type of interviewee, and the interviewee's involvement in the case. Additionally, we used the preliminary interviews to encourage the key contact persons per case to act as an ambassador of the study towards the broader network of stakeholders involved in the case. They were also invited to take the first step in their role as 'case ambassador' by helping the project team with identifying additional stakeholders relevant to the case, and by introducing us to these stakeholders. This is formally known as snowball sampling or *chain-referral* sampling[19]. In most instances, this strategy resulted in successful introductions to other stakeholders relevant to the case. However, in several cases, it proved to be challenging to gain access to the stakeholders who did not work within the organisation of the central contact person. In a limited number of cases, only the central stakeholder could be accessed, and the contact with other stakeholders could not be established due to confidentiality, relationship sensitivity or other reasons.

In-depth interviews with key stakeholders

Based on the preliminary interviews, we conducted detailed interviews both with the central contact person of a specific case and with the additional stakeholders identified. Because of the geographical spread of the interviewees, all interviews were conducted by phone. We used three different questionnaires that were tailored to the three specific case types. The interviews were of semi-structured nature, allowing the researcher to steer the interview towards topics of interest of the study while at the same time allowing for an interview that resembles the natural flow of a conversation, generating information that would not have become apparent through a strictly structured interview.

19 Salganik, M.J. and D.D. Heckathorn (2004). "Sampling and Estimation in Hidden Populations Using Respondent-Driven Sampling". Sociological Methodology 34 (1): 193–239

Validation of interview reports

All interview results were presented in concisely structured interview reports, drafted by the researcher(s) that conducted the interview. The interview reports were sent to the relevant interviewee by email. We asked the interviewees to confirm whether the presented information was accurate and if we could use the information in the study. Such approach allowed the interviewees to improve upon the information we gathered during the interview, and allowed us to further advance our understanding of the case.

2.4. Data analysis and synthesis

After collecting the data for Fieldwork I and II, the preliminary data analysis took place. The current sub-section briefly summarises the key activities of this stage.

2.4.1. Digitally consolidated data

The information from the validated interview reports has been consolidated in a digital file that organises the information per case type, case, respondent, research question and hypothesis, allowing for the anonymisation of the presented data (detaching the data from the interviewee details). The research team has benefited from the digital system which allowed multiple researchers to work with the data simultaneously and from different geographical locations while retaining data integrity and version synchronicity. The data consolidation file was regularly backed up to prevent any loss or corruption of stored data.

2.4.2. Data analysis per hypothesis

The consolidated data has been analysed per hypothesis on a case-by-case basis for each of the three case types separately, by reviewing the extent to which the individual hypotheses are applicable to a specific case, and if applicable, whether the case study information serves to validate or reject the specific hypothesis. By combining this hypothesis validation results across cases and across case types, general conclusions were drawn which are presented in Chapter 3 of this report. The case study information that is not directly linked to specific hypotheses but that nonetheless generates valuable insights has also been included in the analysis in this report.

Important considerations for the study refer to the fact that each successful innovation is unique and represents the result of a joint influence of the ***endless number of factors***. Therefore, when drawing conclusions and developing recommendations, we searched for ***commonalities*** among the success stories (identification of cross-case best practices), with less emphasis on differences. This does not mean that differences were omitted from the study. We report on operational details (including unique characteristics of cases) in case study descriptions.

2.5. Key challenges and solutions

The current section elaborates on specific challenges that we had to overcome during data collection and data analysis phases for Fieldwork I and II, and the corresponding solutions for those challenges.

2.5.1. Challenges and solutions related to data collection

Several practical challenges were encountered during the execution of data collection tasks within Fieldwork I and II. These challenges included language barriers, communicating across different time zones and with different communication methods, delayed responses from respondents, respondents that were sceptical about our study and hesitant to provide information, cases that involved ceased product or process lines, and stakeholders that were unable to participate for specific reasons. We attempted to overcome these challenges by working in a flexible fashion, adapting our methods and working arrangements, and by extensively communicating the nature of our study and its potential benefits to the relevant stakeholders. Below we elaborate on these challenges and solutions in more detail.

Language barriers

When dealing with cases in East Asia, we encountered a language barrier both when trying to establish contact with key contact persons and during interviews with stakeholders. Some representatives of organisations that we targeted were not sufficiently proficient in English to respond to our request. This made it challenging for us to explain the nature of our study, to convince key contact persons to participate in our study, and to conduct interviews with key stakeholders. To overcome this challenge, we added additional members to our team that were proficient in the language of our respondents (e.g., Chinese). This allowed us to keep technically interesting cases in the study and to obtain sufficient information for detailed case study descriptions.

Communicating across different time zones

Due to the geographical spread of the cases (Europe, North America, East Asia), it was often necessary to communicate across different time zones. For some cases, this meant that there was hardly any overlap between office hours of the research team and the regular working hours of the interviewees, which limited the window of opportunity for scheduling interviews. In order to solve this situation, the research team worked in a flexible manner, extending working days and allowing for irregular working hours. This made it possible for the interviewees to have interviews within their office hours also when in significantly different time zones.

Communicating with different communication methods

As many of the engaged stakeholders can be considered so called 'technology enthusiasts', they sometimes preferred communicating through ways that the project team was not equipped to deal with. Several stakeholders insisted on communicating via Skype, an online digital communication service that provides messaging services as well as real-time audio and video messaging across the Internet, and can be used on desktop computers, laptops, portable devices such as tablets, as well as most smart phones. This posed a challenge as these individuals were used to communicating via Skype to such extent that they could not be reached by phone and did not regularly check their email messages. To cope with this challenge, the project team adopted Skype as one of the communication tools. This communication means was used to communicate with stakeholders that would not react to emails and that could not be reached by phone.

Delayed responses from key contact persons and other stakeholders

In some cases, contact persons and other stakeholders reacted to our messages in a delayed manner. This had an unfavourable effect on the project planning. In such cases, we used follow-up emails and phone calls. We also strived to make sure that specific individuals were approached by the same member of the project team in every communication effort.

Cases that involved ceased product or process lines

In a limited number of cases, the product or process lines that we identified as innovations to be included in the study had been discontinued. This limited the extent to which these cases were relevant to the study, and the extent to which stakeholders were interested to discuss the product or process in detail. Those cases were replaced by similar cases of comparable technical nature and geography.

Key contact persons that were sceptical about the study and/or hesitant to provide information

In a few cases, the key contact persons proved to be sceptical about the benefits of participating in the study and were hesitant to provide the project team with information about their case. We attempted to convince them of the potential benefits that participation in the study could have for their innovation, both by phone and by email. In some cases, when stakeholders were still not willing to participate, we had to look for other similar cases from the broader sample, as a replacement.

2.5.2. Challenges and solutions related to data analysis

In this sub-section, we elaborate on challenges and solutions related to the first data analysis.

High complexity of NMP cases

Successful innovations in the field of NMP represent highly complex cases. They cover a wide variety of relations and dissemination channels, each being determined by a partially different set of variables. Furthermore, a weak performance of certain factors may be compensated by a more intense use of other factors, and it does not yet indicate that certain factors should be considered barriers or enablers. To deal with this challenge, we employed a detailed typology of operational activities to be able to capture this large variety of relations and dissemination channels. The presence of barriers in the progression of innovation was linked (whenever possible) to specific activities by means of introducing operationalised questions in the interviews. We also aimed at identifying commonalities among barriers and enablers across all cases in the sample.

Sensitivity of cases to certain environments

The progression of NMP innovations is sensitive to certain environments. Influencing factors may have completely different effects on the progression of innovation in different sectors and technology fields. It is important not only to choose the right level of aggregation, but also to be cautious when judging on good practices across all sectors. When collecting data on individual cases, we gathered additional information on contextual factors that need to be taken into consideration in order to assess its level of transferability not only to another country, but also to different sectors and technology fields.

Diversity of influencing factors

Key factors influencing the progression of NMP innovations are highly diverse, ranging from entrepreneurial skills and competences of individual entrepreneurs to a normative framework and public policies and support services. These factors may be mutually strengthening, neutralising or contradictory. Thus, it is difficult to isolate the separate effect of a certain factor. We strived to make an inventory of various influencing factors from several dimensions. The effects of these factors on the progression of innovations must be, however, treated with great caution. We also paid attention to the total set of factors (clusters of factors) influencing the examined cases, and not only at individual factors.

Causal relationship between factors and results

There is a time lag in the marginal effects of factors such as framework conditions, public policies and public support services, which vary by country/region and sector. This often makes it extremely difficult to associate changes in general framework conditions with changes in the progression of NMP innovations. We aimed at examining the influence of general framework conditions, public policies and public support services on the progression of NMP innovations. However, any conclusions with regard to causal relationships need to be interpreted with caution.

Comparability of data

There is a significant lack in comparable data on the progression of NMP innovations, especially when looking more closely into certain fields of technology and types of actor. Obtaining comparable data becomes possible by using standardised comprehensive interview tools. These data were complemented (whenever possible) with results of desk research and other fieldwork activities.

Quality and volume of information available on each case

The quality and volume of available information differ per case. The overall process of data/information collection was iterative in nature. Besides a comprehensive desk research, this process involved initial interaction between the research team and the key contact persons for each case, followed by a series of in-depth interviews with the key stakeholders.

Interpretation of data

In interpreting the data obtained from the key stakeholders, a two-stage process was instituted, involving at first, a detailed preliminary review and collation of all data received on one case and the identification of any deficiencies/errors etc. The latter was then communicated to the relevant stakeholders and explanation or clarification was sought.

3. Key findings and conclusions

The current chapter presents the key findings of the study. It is important to emphasise that ***these findings are based on a thorough qualitative examination of a limited number of cases***. Such approach allowed us to a large extent to reconstruct the commercialisation trajectories of the analysed cases and to obtain a high level of detail for a comprehensive analysis. At the same time, ***any generalisations of conclusions to the whole population of NMP cases should be made with great caution, and should take into account the fact that the analysis was conducted based exclusively on examples of a smaller population of commercially successful NMP cases with a limited involvement of public funds***.

We begin with general findings applicable to all analysed NMP innovations, and then move on to the findings particularly relevant to the certain types of NMP innovations. To illustrate the presented findings, we refer to the examples from the sample.

3.1. High diversity of NMP cases

NMP innovations are complex, multidisciplinary and of potentially disruptive nature. The study showed significant differences between the progression of innovations within different NMP categories.

NMP innovations imply complex, multidisciplinary and potentially disruptive nature of the innovation cycle. Furthermore, each commercialisation path is unique. Finally, NMP market is not a single market but a series of enabling technologies that provide groundbreaking solutions to high-value problems in every industry[20]. All these factors suggest that any generalisations regarding the innovation cycle of such innovations should be made with great caution.

In the course of the whole study, we split all NMP innovations into three main categories: New Products, New Materials and New Production. Our empirical analysis confirmed the ***significant differences between the progression of innovations within these categories***.

New Products and New Materials categories proved to have somewhat comparable innovation trajectories, with key activities like research, exploring market opportunities, interaction with potential users, prototyping, industrialisation, scaling up and distribution & sales. A key difference refers to the fact that the innovation trajectory of New Materials typically feeds into the innovation trajectory of New Products. Additionally, since materials are embedded in products, any risks that exist in the

[20] Tolfree D., Jackson M.J. (2008) "Commercializing micro-nanotechnology products", CRC Press

product market are amplified in the materials market. Consequently, these additional risks need to be taken into account when, for example, designing marketing strategies and deciding on manufacturing form and scale for new materials.

Larger differences can be observed when comparing New Products and New Materials with the progression of New Production innovations. The latter category includes the new ways of organising manufacturing and new business models. An innovation cycle of a production system is something completely different than an innovation cycle of a material or a product. It typically starts with the initial system design and synthesis according to the specified objectives and constraints. This step is then followed by modelling, analysis and simulation. Then the final design is realised, implemented and used in production. The production system undergoes re-design and reconfiguration, throughout its operation and as new requirements emerge and changes are required. Consequently, in case of New Production, one has to deal with different types of activities, decisions and challenges when compared with New Products and New Materials, and these differences should be taken into consideration when developing effective policy measures. We will get back to this point in Chapter 4 of the report.

Despite the differences among the categories, some key common factors can be found that refer to the whole pool of NMP innovations. These common factors are presented below.

3.2. Innovation cycle as a continuous process with parallel activities

Rather than a chain of subsequent steps, NMP innovation trajectory is a continuous process consisting of closely interrelated activities.

When illustrating a progression of an innovation over time, from its inception as a result of research (exploration) to its broad adoption by the market (exploitation), existing literature typically views this progression as a sequence of several separate steps. That was also the approach that we initially took when developing an analytical framework for the study. The study, however, showed that ***these steps are usually of continuous nature and take place in parallel***. It is therefore more appropriate to call specific elements of the innovation trajectory *activities* rather than steps. Furthermore, rather than a closed cycle, ***the NMP innovation trajectory model represents a continuous process with close interrelations between various activities***. One additional activity not previously included in the model but playing a key role in the innovation trajectory of all successful cases refers to the ***interaction with users, designers and engineers, which happens throughout the whole innovation trajectory***.

Below we elaborate on these findings in more detail.

3.2.1. From subsequent steps towards parallel activities

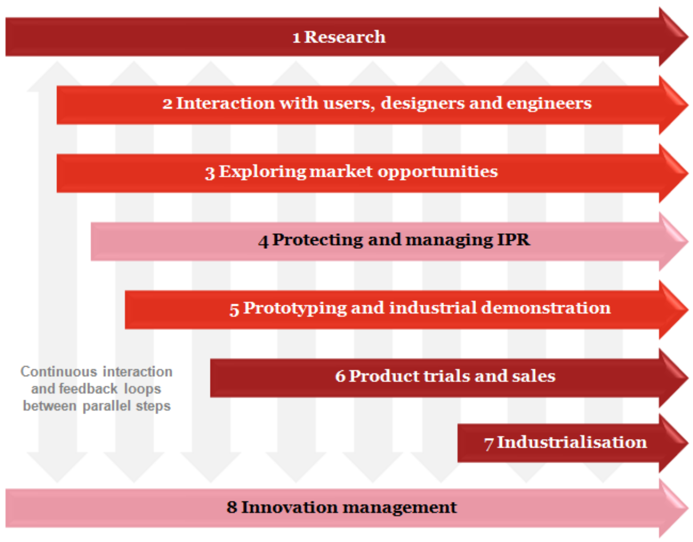

FIGURE 3-1: Revised innovation trajectory model

The empirical analysis showed that the innovation cycle for new NMP products is not a linear system, ***it is a continuous iterative process, and it implies several loops***. Such feedback loops mainly refer to incorporating feedback from designers, engineer community and users. Activities such as incorporating feedback and exploring market opportunities are reported to take place in parallel with other key steps of the innovation cycle (e.g., research, prototyping, industrial demonstration etc.). In case of successful innovations, incorporating feedback and exploring market opportunities start from the very beginning of the innovation cycle, not long after the beginning of research activities. Furthermore, research itself is typically of ongoing nature, closely linked to feedback incorporation and exploration of market opportunities.

Additionally, given a complex nature of NMP innovations, protecting and managing Intellectual Property Rights becomes a continuous process too. Finally, NMP innovations typically represent complex products that often imply trials on the client's side. Since user feedback plays a prominent role in the innovation cycle and allows for further advancement of the product, actual product trials and sales often start in the middle of the innovation cycle rather than closer to the end.

Figure 3-1 presents a revised innovation trajectory model. The model illustrates a progression of an innovation over time, from its inception as a result of research (exploration) to its broad adoption by the market (exploitation). The duration of specific stages can be accelerated or decelerated by factors such as increasing or decreasing investments, market demand, standardisation and regulation. The model is broadly generalised and represents a simplified version of the course of

Successful NMP innovations result from a combination of both technology push and market pull. The extent to which either one dominates depends on the nature and the application sector of the innovation.

development of NMP innovations. Some deviations from this generalised model are likely to be found in specific cases. Nevertheless, ***the model can serve as a basis for tracing and understanding various stages of creation and development of NMP innovations***.

3.2.2. Combination of both technology push and market pull

The analysed cases suggest that ***successful innovations result from a combination of both technology push and market pull***. Both need to be present simultaneously, i.e., there needs to be a clear demand/market for the innovation, but at the same time, the technology should be at the level that is advanced enough to satisfy the existing demand and to create new markets. The latter is particularly relevant to high-tech NMP products. ***Which of the two, technology push or market pull, dominates the process depends on the nature and the application sector of innovation***. The more technically complex the innovation is (which implies extensive engineering efforts), the more important is technology push (see, for example, the case on NAO Robotics Platform). This trend can also be related to the need to create markets for innovations which are mainly technology-driven. The specific need for NMP products to create new markets was several times referred to by the interviewees as resembling the early computer electronics world of 1970s-1980s. Similarly, at that time, there was a need to create awareness about radically new products among potential users and educate the users on what these products actually are and what they can. NMP products which imply less technical complexity and are oriented towards mass customer, are more market-driven (see, for example, the cases on Silverlon Wound Care and on APADENT and APAGARD Nanohydroxyapatite Toothpaste). Furthermore, the successful innovations from the sample often implied offering customers technically complex products for a highly affordable price.

3.2.3. Duration of the innovation cycle depending on sector rather than technical complexity

Initially, we hypothesised that the total innovation cycle from research to the market for NMP products takes about 10-20 years. We aimed at measuring the time taken for the particular innovation to reach commercialisation, approximate duration of different phases of the progression of an innovation, and the time taken for the firm to recoup its expenditure on a particular innovation.

The total duration of the innovation cycle for NMP products proved to depend on the sector rather than on the technical complexity of the innovation. Several

The total duration of the NMP innovation cycle depends on the application sector of the innovation and is influenced by regulation.

innovations from the sample managed to reach the market within a couple of years[21] (for example, NAO Robotics Platform, Fiber Laser PFL-200, Envirox™, Advanced Marine Coatings, T-Sight 5000). Interestingly, these innovations demonstrated high technical complexity[22]. At the same time, these innovations required almost immediate user involvement in the process of further advancement of the product (NAO Robotics Platform in particular). For innovations related to the medical sector, the regulatory environment was reported to serve as a key reason for a delayed market entry (15-20 years for Silverton Wound Care, and 7 years for Epilepsy Bracelet). Interestingly, APADENT and APAGARD Nanohydroxyapatite toothpaste was initially positioned as cosmetics which allowed the company to introduce the product to the market after 2 years of research. However, it took the company 15 years before they were allowed to present the product as a medical treatment (this time period included multiple stages of clinical trials and getting all the necessary approvals). For DFB Laser, a potential future barrier was that European environmental legislation may ban particular semiconductor production material that contains arsenic.

Consequently, ***in general, there is a clear trend that companies try to introduce the NMP innovations to the market as soon as possible***. In some cases though, especially if the product falls under the category of medical devices, equipment or treatment, time-to-market significantly increases because of regulatory requirements.

In some cases, however, ***regulation may act as an accelerator for the innovation's introduction to the market***, e.g., Advanced Marine Coatings and tripleO cases. Both innovations have a direct link to environmental regulation. In case of tripleO, evidence was found that the coating reduces drag by up to 39% on a coated surface. By reducing drag, motorised solutions, such as aircrafts or cars, become more fuel efficient as the engines have to compensate for less friction. With environmental regulation becoming increasingly more stringent and with airlines trying to minimise their carbon footprint, tripleO was provided a great opportunity to market their product. The company could emphasise the environmental friendliness of the product while offering clear-cut benefits in both a higher fuel efficiency itself and a subsequent reduction in carbon dioxide emissions. Similar conclusions can be drawn for the cases of Envirox™ and Advanced Marine Coatings.

[21] The reference here is made to the time spent exclusively on product development (not basic research)
[22] Technically complex innovations usually are based on the results of previous basic and/or applied research which may take up to several decades. Claims about short time-to-market of such innovations should therefore be made with great caution.

3.2.4. High complexity of innovations

NMP innovations are based on not just one innovation, but a cluster of innovations, often as many as a dozen. The more technically complex the innovation is, the more different types of innovations are involved in it. NMP innovations often combine various key enabling technologies (for example, Fiber Laser PFL-200 which combines nanotechnology, photonics and new materials; Q.E.F. Electronic Innovations Epilepsy Bracelet which uses several innovations in the field of microelectronics, such as wireless transmitters, several electrical components).

NMP innovations often combine various key enabling technologies. The more technically complex the innovation is, the more different types of innovations are involved in it.

Products based on NMP and enabling technologies in general often draw not simply upon multiple innovations, but upon multiple innovations from various disciplines. The filing of a patent for enabling technologies often involves a team of scientists/engineers representing many scientific disciplines collaborating on a technology comprising multiple components, each of which might require multiple IP rights. ***That multidisciplinary nature makes IP for enabling technologies distinctive from other technologies*** since the technology is typically developed through expertise in the fields such as biology, chemistry, engineering, and materials science.

The complexity of IP rights for enabling technologies, in turn, means that their scope is much broader than in other technologies, and it involves more players in the field than might appear at first glance. For example, a basic nanotechnology patent may have implications for semiconductor design, biotechnology, materials science, telecommunications, and textiles, even though the patent is held by a company that works in only one of these industries. Unlike other new industries, in which the patentees are largely actual or at least potential participants in the market, a significant number of nanotechnology patentees owns rights not just in the industry in which they participate, but in other industries as well[23].

The analysed cases were supported mainly by private funds. Whenever public funds were used, those were predominantly supporting basic research and first prototyping activities (up to TRL 5: validation in a relevant environment). Several examples were also identified where public funds provided support beyond TRL 5, e.g., funding for the development of a marketable product and first commercialisation activities.

23 Nanotechnology and Intellectual Property Issues, Nanowerk 2006
http://www.nanowerk.com/news/newsid=1187.php

3.2.5. *Financial support from diversified funds*

Several types of funds used to support NMP innovations can be identified such as personal savings of entrepreneurs; FFF (Friends, Family and Fools); business angels; venture capital investors; institutional funds (risk-bearing capital), e.g., retirement funds; bank loans; grants from private funds, e.g., design competitions; and grants from public funds.

Interestingly, the analysed cases suggest that innovation funding was hardly an issue that blocked the progression of the innovation. ***In most cases, the innovations were supported purely by private funds coming from own savings, company's own funds and business angels in the beginning, and venture capital investors at later stages***. Whenever the entrepreneurs needed to raise external funding, the key success criteria for convincing investors were reported to be the charismatic nature of the entrepreneur (i.e., the ability to convince and negotiate), technically well-prepared presentations and rigorous market research. One particular characteristic refers to the technical complexity/price ratio. As mentioned above, the innovations that managed to attract additional funding often implied offering customers technically complex products for a highly affordable price.

In some cases, companies could manage without raising any external funds (e.g., APADENT and APAGARD Nanohydroxyapatite Toothpaste). Entrepreneurs establishing a new company at times had market experience and owned/sold other companies, and as a resultthere was no need to raise any external funds for commercialisation activities.

The public funds used by the analysed cases include national grants for joint research projects between university and industry by national ministries, tax deduction schemes for R&D activities, loans with governmental guarantees, and other measures stimulating interaction and exchange between the universities and SMEs, e.g., Dutch innovation vouchers.

Public funding in the case of Advanced Marine Coatings
The company participated in SkatteFUNN tax deduction scheme offered by the Norwegian government. The SkatteFUNN scheme is an indirect funding scheme. Support takes the form of a tax deduction up to 20% of the costs related to R&D activity. The tax deduction is awarded on top of the ordinary deductions[24]. All companies subject to taxation in Norway are eligible to apply for a deduction, regardless of branch of industry, size or geographic location. The company made use of this scheme for the period of three years (which is the maximum allowed within the scheme).

[24] http://www.forskningsradet.no/prognett-skattefunn/About_SkatteFUNN/1228296913369

Public funding in the case of NAO Robotics Platform
NAO Robotics Platform was partially developed based on a PhD funded with a CIFRE grant by the French National Agency of Research and Technology. The CIFRE grant is meant for joint research projects between students (typically for a PhD), university research departments, and private companies. The objective of the grant is to stimulate private companies to invest in R&D, while universties are stimulated to shift more towards applied research.

Public funding in the case of DFB laser
During the research phase and the initial commercialisation phase, the researchers received regional subsidies in the form of 50% co-financing from the German state of Bavaria for the development of a marketable product. In the early days of the spin-off company, the company received funding from the Fourth Framework programme.

Public funding in the case of Green Biologics Limited Fermentation Process
Green Biologics Limited Fermentation Process received several grants. The UK Department of Trade and Industry-led Technology Programme provided funding for developing sustainable biofuel. This funding enabled the company to grow quickly both in terms of financial capital and human resources. The company was awarded by another grant from the North West Development Agency under the scheme called "Grant for Business Investment". The company qualified for this grant on the basis that they would create up to 30 new jobs in an area with high unemployment.

Public funding in the case of DyeCoo
DyeCoo benefited from a mix of schemes offered by the Dutch Government, such as Environment & Technology grant; "Innovatief Borgstellingskrediet", a loan in which government plays a role of guarantor for the major part of the loan, a measure designed to support SMEs working in a highly unpredictable environment; WBSO, a tax incentive of the Dutch government in which a portion of labor costs for R&D is compensated; and Innovation vouchers. Innovation vouchers scheme aims to enable SMEs to buy knowledge and strategic consultancy from research institutions through vouchers and thus to stimulate interaction and exchange between the knowledge suppliers and SMEs. The knowledge supplier can then hand in the voucher to the Innovation Agency and receive payment.

Consequently, ***in most cases, public funds were predominantly used for supporting basic research and first prototyping activities*** (up to TRL 5: validation in a relevant environment). At the same time, ***several examples were identified where public funds provided support beyond TRL 5, e.g., funding for the development of a marketable product and first commercialisation activities*** (regional subsidy of the German state of Bavaria in the case of DFB laser), grants for job creation in the region ("Grant for Business Investment" by the North West Development Agency in the case of Green Biologics Limited Fermentation Process), as well as loans in which government plays a role of guarantor to support SMEs working in a highly unpredictable environment ("Innovatief Borgstellingskrediet" by the Dutch Government in the case of DyeCoo). Some of the analysed cases therefore benefited from ***public support for the activities closer to the market*** which can partially explain the success of the exploitation of their research results. Interestingly, as mentioned above, despite the involvement of public funds, the majority of funding for the analysed cases came from private sources. ***The cases thus demonstrate the use of public funds for attracting private funding rather than for substituting it, i.e., a concept of 'smart' public funding***. We will elaborate on public support for the activities closer to the market and on 'smart' funding in the recommendations part of the report.

3.2.6. Evolution of activities in time

The continuous activities within the NMP innovation trajectory evolve over time and can be linked to Technology Readiness Levels.

As mentioned above, the NMP innovation cycle proves to consist of various continuous activities taking place in parallel with each other. ***The continuous nature of those activities suggests that they evolve over time*** which was confirmed by the findings of this study. By this we mean that ***while from a strategic perspective, the essence/objective of these activities remains the same all the time, the way these activities are performed operationally, as well as means involved change in time***. Furthermore, ***it is possible to establish a link between these changes and different Technology Readiness Levels (TRLs)***. This link is presented in Figure 3-2. Below we provide short descriptions of each TRL[25,26].

1. *Basic principles observed and reported*. At this lowest level of technology readiness, ideas are transitioning out of fundamental research into applied research and development. This transitioning occurs in paper studies of a technology's basic properties.

2. *Technology concept formulated*. This level is where research gives way to invention. The application may be speculative, in the sense that no proof or detailed analysis exists to support the assumption the invention will work as promised. Paper studies are still occurring.

3. *Analytical and experimental critical function proof of concept*. Now formal analytical (including simulations) and laboratory studies are conducted to evaluate the performance predictions that have been made. The emphasis is on proof of concept, that is, critical but separate elements of the technology.

4. *Component and/or breadboard validation in a laboratory environment*. By integrating several technological components, a bread board or brass board is created that establishes that the pieces will work together. This bench top crude prototype validates the utility of the knowledge underlying the technology.

[25] DOD, July 2009, Technology Readiness Assessment (TRA) Deskbook
[26] Speser P.L. (2006) The Art and Science of Technology Transfer, John Wiley & Sons, Inc., Hoboken, New Jersey

5. *Component and/or breadboard validation in a relevant environment*. Now a prototype with key functionality exists that provides a “high fidelity” laboratory integration of the components. The prototype, in turn, enables more testing, such as testing in a simulated environment. The testing may involve validating thresholds that suggest the technology will operate acceptably in a relevant environment.

6. *System/subsystem model or prototype demonstration in a relevant environment*. The prototype now is a fully functioning prototype or computer model that enables testing performance yields in a “high fidelity” laboratory environment or in simulated operational environment, like a compression or environmental chamber. This level involves alpha testing.

7. *System prototype demonstration in an operational environment*. The prototype is now taken out of the lab and put in the hands of end users in their actual working conditions. This is beta testing. By the end of beta testing, the technology has been proven to work in its final form and under expected operational conditions. Ideally, what is being tested is the intended or pre-production configuration to determine that the technology does meet the design specifications and has operational utility. This testing is the basis of acceptance testing.

8. *Actual system completed and operationally qualified through test and demonstration*. The technology has been proven to work in beta testing and has been tweaked to address any issues that emerged there. In almost all cases, this TRL represents the end of the development process.

9. *Actual system, proven through successful practical use*. The technology is ready for its deployment. It may still involve beta testing, as the last “bug fixing” occurs. Sometimes this bug fixing endures forever.

In the remainder of this chapter, we will elaborate on each of the activities in more detail. It is important to note that the evolutionary model represents a generalised and universalistic version of the reality, and is based on the trends identified in the majority of the analysed cases. As mentioned before, however, each innovation is unique, and not all operational activities are relevant to a particular case, nor do they necessarily have to happen in the same sequence.

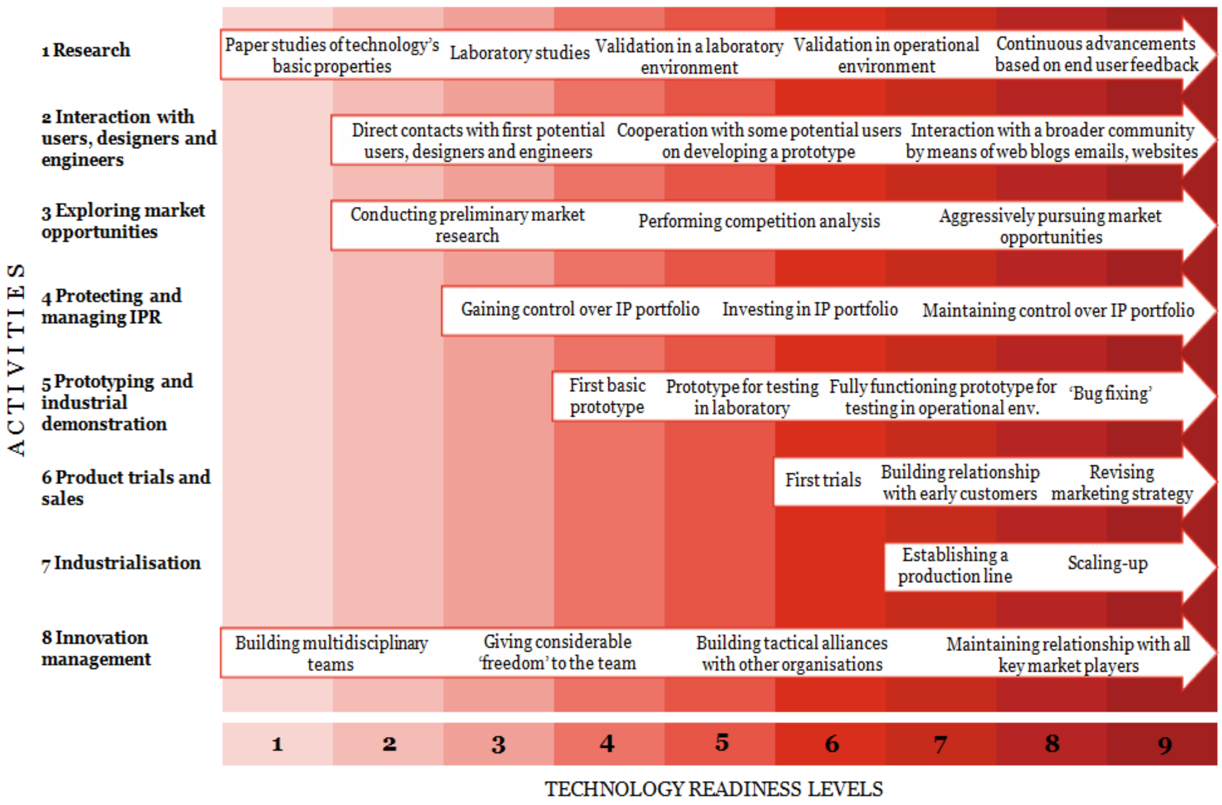

FIGURE 3-2: Evolution of activities throughout various Technology Readiness Levels (TRLs)

3.2.7. Activity 1 Research: close involvement of industry and diverse funding sources

An innovation typically begins as a result of research, leading to a set of discoveries. We consider research to be investigation and experimentation, while discovery is the result of such research and entails the realisation of the previously unknown concept, idea, principle or phenomenon (e.g., new material, new process). Research thus represents an activity that is focused on the development of knowledge in the form of discoveries.

Several common success factors were identified within the research phase:

- ***Highly motivated and highly skilled research team*** (people with talent and passion for this specific research); increase in motivation can partially be explained by a technically challenging nature of the innovation (in contrast to more typical product development within a company);
- ***CEO's commitment and support to the project*** (including allocation of company's funds);

- ***Close collaboration between companies and universities/research institutes*** (including using research facilities of a university/research centre which allows for access to unique and expensive equipment and social networks of academic researchers).

A list of common challenges and barriers includes the following:

- ***Available knowledge within the company/team***: the members of the team typically had a strong engineering background, but the innovation required knowledge in many different fields simultaneously, e.g., electronics, mechanics, mathematics;
- ***Good knowledge of the state-of-the-art developments in the field***;
- ***The need to tackle technical problems nobody ever tackled before***;
- ***The need to balance between quality and price due to budget limitations*** (sometimes decisions had to be made to go for low cost components which created even more technical challenges afterwards; e.g. NAO Robotics Platform).

Close involvement of industry in research activities

Initially, we hypothesised that while NMP-related basic research is typically conducted by public actors, ***the transition from basic research into applied research and development is typically made with close involvement of industry representatives***. We were not always able to confirm this hypothesis based on the analysed sample of cases because of a number of reasons. First, in most cases, the analysed innovations have been traced back to applied research only. At that stage, the companies commercialising the innovation were the same companies that were conducting applied research. As for fundamental research that preceded applied one, it often took several decades and was based on a complex system of discoveries that developed in parallel and are highly difficult to trace. Second, cases for which it was possible to trace the innovation's development back to fundamental research often implied creation of a spin-off company from a university, with the same researcher taking on the CEO's position. Nevertheless, in such cases, people with relevant industry expertise were typically involved in the team, which confirms the abovementioned hypothesis.

Diverse funding sources

Several scenarios can be observed with regard to research funding of NMP innovations. In some cases, research was exclusively funded from private sources including client payments (e.g., Advanced Marine Coatings, T-Sight 5000), sometimes with the company's own investment being the only funding source (e.g., Fiber Laser PFL-200, Q.E.F. Epilepsy

Bracelet, APADENT and APAGARD Nanohydroxyapatite Toothpaste, Envirox™). In other cases, public funds were involved such as research grants from national ministries (e.g., NAO Robotics Platform; Silverlon Wound Care Dressing; DFB laser).

3.2.8. Activity 2 Interaction with users, designers and engineers: active involvement of community from the very beginning

This activity was not included in the initial innovation cycle model. As a result, no hypotheses were formulated beforehand. At the same time, the empirical analysis showed that for successful NMP innovations, this activity plays a central role in the whole innovation process. Therefore, it should not be overlooked when analysing the progression of NMP innovations.

Successful NMP innovations thus demonstrate an ***active involvement of a broad community of users, designers and engineers from the very beginning of their innovation trajectory***. This involvement may take different forms such as:

- ***online collaboration platforms*** with a broader community (e.g., websites where people from all over the world are invited to submit their product designs, work on the improvement of a certain technology or production process);
- ***direct contacts*** with users, designers and engineers at company's premises, conferences, fairs and/or other events;
- interaction with a broader community by means of ***web blogs and emails*** (the current study confirmed that the best way to reach technology enthusiasts is to place a message on the Internet; direct email will reach them too, and provided it is factual and contains new information, they will read it cover to cover);
- engagement in ***open source approach*** (although this measure is not typical for all analysed cases, and some companies still find it too risky; companies that managed to benefit from open source approach share with public domain only some elements of their technology, protecting the rest in the form of IP or trade secrets).

Companies often engage in close cooperation with users to both improve the product and to better position it on the market. This was especially true in the cases of NAO Robotics Platform, Q.E.F. Epilepsy Bracelet, Fiber Laser PFL-200 and tripleO. In case of Fiber Laser PFL-200, the prototype was developed together with the University of Tokyo research lab which represented a potential customer. The close cooperation directly resulted in feedback from the potential customer, which was incorporated in the design.

Interaction with users in the case of NAO Robotics Platform
NAO Robotics Platform showcased an extensive cooperation with end-users. By having a short-loop between research, in-house manufacturing and users, they received a lot of feedback. It was key for Aldebaran Robotics to quickly incorporate this feedback, i.e., be reactive to market demand. Thanks to the close cooperation with users, the product was both rapidly improved and better positioned in the market.

Interaction with users in the case of Local Motors
Their production method of C.O.O.L. cars is an acronym of Community, Open source, Ownership experiences, and Local production. The community refers to the people around the collaboration platform and open days at their local factories. This community develops the designs or buys the vehicle and thus is highly important for the company's success.

Interaction with users in the case of Ponoko
User involvement was crucial for Ponoko's user manufacturing platform. Most of time and resources was spent not on the technology side of Ponoko, but on who would use Ponoko and why. It was important to have at least part of the concept done as soon as possible, so that the company could interact with customers. The customers then could shape the company's understanding of how the concept was received, and the Ponoko company could shape the customer's understanding of the concept. Four months into the development phase they brought alpha customers in.

Interaction with users in the case of MakerBot
In the case of MakerBot 3D printer, a dedicated user community is involved in design and upgrading of the product, related software and applications (what can actually be printed out). The MakerBot community is a group of operators, engineers, hackers and 'ordinary' users working on projects all around the world. It as a group that meets in real life and has its own mailing list dedicated to MakerBotting. They meet each other, trade tips and tricks and print things together. Geographically, the community is spread across North America, Europe, Argentina, Australia and New Zealand.

Interaction with users in the case of Ricoh
The development of the flexible cart line production system at Ricoh has benefited from early-stage user involvement. Shop-floor workers were involved in the planning of the implementation of the cart lines and were involved with testing the cart lines and the individual carts as well as evaluating their performance. This has allowed for timely feedback to the engineers on issues that might not have occurred to them otherwise.

In the case of Q.E.F. Epilepsy Bracelet, the initial prototype was constantly being improved based on customer feedback. In the case of tripleO, the benefits of the coating were further explored in close cooperation with their first industry partner, Easyjet. The field trial tests allowed the tripleO company to better position their product in the market and to learn more about the advantages and disadvantages of it. Similarly, APADENT and APAGARD Nanohydroxyapatite Toothpaste, Advanced Marine Coatings and Envirox™ benefitted from extensive communication with and feedback from early adopters.

Interaction with users strengthened the companies' ability to quickly adapt to new market demand or circumstances. The feedback provided by the users allows for rapid improvement of the product, but it also requires companies to have the ability to react.

3.2.9. Activity 3 Exploring market opportunities: obtaining good knowledge of the market

This activity implies rigorous marker scans, negotiations with potential partners and consumers. In the previous sub-section, we already addressed the notions of technology push vs. market/demand pull. NMP innovations have a huge variety of applications, and companies often choose for a so called “platform strategy”. This strategy implies developing a technology with multiple applications; however, it makes it much harder for most NMP companies to succeed. While the addressable market size increases, the probability of success in each of the sectors considerably reduces, as focus is split between multiple customers with multiple needs[27].

Conducting preliminary market research

In technology transfer, there are two key types of markets. The first market is ***the market of the innovation’s developers***, i.e., the market for licensing, joint venturing, raising capital, or otherwise commercialising the technology. The second market is ***the market of the innovation’s buyers***, that is, the market in which the potential commercialisation partners sell something with the aid of the technology to their customers: the end users[28].

It is often not immediately clear who is in the arena, and buyers and sellers may have trouble finding each other. Therefore, asking someone likely to be a stakeholder about the market can be highly useful. Knowledgeable people can be found in relevant associations, university/industry centres, and government agencies. The stakeholders can also indicate other organisations where the technology will be used, be procured, be sold, etc. It is often enough to have five to seven calls in order to get a fair idea of who is in the arena[29].

Initially, we hypothesised that in case of successful innovations, there is a good understanding of a set of organisations in which the innovation can be applied plus those organisations that want to influence who uses the innovation. Furthermore, there is a good understanding not only of the market for that particular innovation, but also of the agendas and markets of its potential buyers. These hypotheses proved to be valid for most of the cases except Silverlon and Advanced Marine Coating. Those two companies did not do any extensive market research and relied on their

[27] Commercialisation of nanotechnology – Key challenges, Nanoforum report 2007
[28] Speser P.L. (2006) The Art and Science of Technology Transfer, John Wiley & Sons, Inc., Hoboken, New Jersey
[29] Speser P.L. (2006) The Art and Science of Technology Transfer, John Wiley & Sons, Inc., Hoboken, New Jersey

own knowledge of the market. In case of Silverlon, the company lacked the financial means for market research activities.

In case of Fiber Laser PFL-200, the company did in-house study to survey the laser market, though no professional in-depth market analysis was done to assess market opportunities. In case of Q.E.F. Epilepsy Bracelet, both the distributor and the company did research on what type of clients could benefit from the product. At the same time, the agendas and markets of potential buyers were not explored, which resulted in great challenges in the diffusion of the innovation.

Market research in the case of NAO Robotics Platform
For NAO Robotics Platform, the company did an in-depth competition analysis and already set the goal to secure the RoboCup[30] deal at an early stage, showing their awareness of the market. The company also understood the agendas of their potential buyers (e.g., that Aibo needed to be replaced on the Robocup platform).

Market research in the case of APADENT and APAGARD Nanohydroxyapatite Toothpaste
The CEO had a basic understanding of the market and the need for such product on the market. At the same time, in the beginning, the company did not know that consumers will like the whitening effect of the toothpaste. It is only after the feedback was collected, they came to know the public perception of the benefits provided by the toothpaste.

Performing competition analysis

There are two sets of competitors for any technology: (1) competitors relevant when selling goods embodying or made with the technology to end-users, and (2) competitors relevant when determining who is developing substitute technologies. ***In case of ad hoc diffuse markets, it is often difficult to identify and track the competition***. At a centralised market, like a trade show, one can walk around and see who is offering what. In case of NMP products/services/processes, one cannot do that, thus it is far more important ***to aggressively pursue opportunities***. Otherwise the window of opportunity is likely to close before one is even aware there is competition. The window of opportunity is the period in which a new technology can be introduced into a market niche. It opens when something changes in either the immediate practice where the technology will be inserted or in the larger value and supply chains within which the practice is embedded[31].

[30] RoboCup is an international robotics competition founded in 1997. The aim is to develop autonomous soccer robots with the intention of promoting research and education in the field of artificial intelligence. The name RoboCup is a contraction of the competition's full name, "Robot Soccer World Cup", but there are many other stages of the competition such as "Search and Rescue", "RoboCup@Home" and "Robot Dancing".
[31] Speser P.L. (2006) The Art and Science of Technology Transfer, John Wiley & Sons, Inc., Hoboken, New Jersey

We hypothesised that in case of successful innovations, segmentation of competitors is performed before entering the market. ***Different scenarios***, however, ***were observed in different cases***. Some companies explored the competition by means of either relatively simple Internet search or by following a more rigorous approach including conversations with potential clients and/or competitors (e.g., Q.E.F. Epilepsy Bracelet, Envirox™, NAO Robotics Platform). Some went even further and made competition analysis their regular activity rather than a one-time exercise (e.g., T-Sight 5000).

In some cases, however, the competition analysis was not performed either due to perceived strong knowledge of the market and lack of competition, or because of limited financial resources. For example, in case of APADENT and APAGARD Nanohydroxyapatite Toothpaste, the company considered the product to be revolutionary in nature in terms of remineralising properties. No attention was therefore paid to competitors. Once the product was successful, the market was flooded with look-alikes, then the company finally started to look at the competitors. It readjusted its strategy to not only position the toothpaste as a whitening agent, but also to stress its anti-caries properties. Similarly, in case of Advanced Marine Coatings, the owners of the company were convinced that the marine industry lacks such technology, so they saw an opportunity on the market and no competition. In case of Silverlon Wound Care dressings, the company lacked financial means to perform research on competitors.

Aggressively pursuing market opportunities

We also hypothesised that in case of successful innovations, ***market opportunities were pursued aggressively***. This hypothesis proved to be valid for most of the analysed cases. For example, in case of APADENT and APAGARD Nanohydroxyapatite Toothpaste, several routes were followed to promote and sell the product, ranging from direct sales to more innovative channels such as selling the product through system of "in-company co-op" route, a system under which companies purchase mainly health-related goods in bulk for resale to their staff, at or near cost, as a way of offering side-benefits to their employees. Silverlon Wound Care dressings were 'aggressively' distributed through direct sales at hospitals. In case of Envirox™, the company made direct contacts with different potential customers all over the world.

In other cases, however, no aggressive pursuing of market opportunities was observed. For example, in case of Fiber Laser PFL-200, the team mainly consisted of people with technical background, with limited experience in sales. Lack of aggressive strategy proved to be a setback for Q.E.F. Epilepsy Bracelet. Efforts of the distributor were mostly limited to existing clientele, on the Benelux market. The company did not actively target health insurers which represent a large potential market.

3.2.10. Activity 4 Protecting and managing Intellectual Property Rights: confidentiality measures, multidisciplinary teams and just-in-time decisions

Products based on enabling technologies often draw upon innovations across multiple disciplines. Not only are the applications of enabling technologies novel and complex, but they are characterised by an unprecedented amount of requisite collaboration from diverse scientific disciplines. Unlike other areas of technological Intellectual Property (IP), ***IP for enabling technologies is distinctive because the technology is typically developed through multidisciplinary expertise***, often in the fields such as biology, chemistry, engineering, and materials science.

The complexity of IP rights for enabling technologies means that ***there are potentially more players in the field than might appear at first glance***. For example, a basic nanotechnology patent may have implications for semiconductor design, biotechnology, materials science, telecommunications, and textiles, even though the patent is held by a firm that works in only one of these industries. Unlike other new industries, in which the patentees are largely actual or at least potential participants in the market, a significant number of nanotechnology patentees owns rights not just in the industry in which they participate, but in other industries as well[32].

Different scenarios of IP creation

We hypothesised that most patents in the area of NMP are generated by either large companies, by universities, or by government labs. We also anticipated that many startups in NMP get at least their initial IP from universities or government labs[33]. Within the sample of analysed cases, we, however, observed several scenarios:

- ***Companies got their initial IP from universities or large companies*** (e.g., APADENT and APAGARD Nanohydroxyapatite Toothpaste; Silverlon Wound Care dressings; DFB laser);
- ***Companies filed patents themselves based on own research*** (e.g., Fiber Laser PFL-200; only in the beginning - NAO robotics research platform; Envirox™);
- ***Companies licensed patents from small companies*** (e.g., Advanced Marine Coatings);
- ***Companies did not file any patents at all*** (e.g., Q.E.F. Epilepsy Bracelet, NAO robotics research platform; T-Sight 5000); the key

[32] Nanotechnology and Intellectual Property Issues, Nanowerk 2006 http://www.nanowerk.com/news/newsid=1187.php

[33] Waitz A., Bokhari W. (2009) “Nanotechnology Commercialization Best Practices”, Quantum InsightSM, http://www.quantuminsight.com/papers/030915_commercialization.pdf

reason for not filing any patents refers to the risk of disclosing the way the technology works and making it relatively easy for other companies (especially big players) to come up with a substitute and finding ways to circumvent the patent, and patent dispute resolutions are associated with high financial burden which small companies cannot afford. In these cases, companies work with non-disclosure agreements and trade secrets.

Consequently, different scenarios are possible regarding the creation of IP for NMP products, and ***there is no one best way to deal with IP***. It depends, among others, on whether IP already exists or needs to be created, the risk of substitution, as well as the size and financial capacity of a company.

Multidisciplinary team involved in IP creation

We also hypothesised that filing of a patent for a NMP innovation often involves ***a team of scientists representing many scientific disciplines collaborating on a technology comprising multiple components, each of which might require multiple IP rights***. This hypothesis proved to be valid for most of the analysed cases (e.g., Fiber Laser PFL-200, NAO Robotics Platform, APADENT and APAGARD Nanohydroxyapatite Toothpaste, DFB laser, Envirox™, Advanced Marine Coatings). Other analysed cases either did not have a patent portfolio at all (e.g., T-Sight 5000) or did not imply the involvement of a large team of multidisciplinary scientists.

In many cases, patents were applied for without any problem (e.g., NAO Robotics Platform, DFB Laser). In two cases, however, patent filing was somewhat troublesome. In case of Q.E.F. Epilepsy Bracelet, the company decided not to patent the innovation because they hypothesised that they would never be able to afford the legal fees if a large company would copy the innovation. They preferred to have secrecy in their solution as opposed to patenting it as they did not see the patent as a sure way to protect their investment. For Fiber Laser PFL-200, the company was forced to hold back its filing. The European patent office took a long time to process this patent application. Eventually, the company decided not to file the patent in Europe.

IP ownership means challenges

Interestingly, ***most of the analysed cases did not report any issues related to IP ownership***. Three of the analysed cases, however, reported several specific challenges which shows the potential negative impact of not well planned management of IP between partners. In case of Fiber Laser PFL-200, the raw material (carbon nanotube) supplier asked for having their name on the patent which ruined the relationship between the company and the supplier. In case of Silverlon Wound Care dressings, patent litigation was initiated between the original inventor and the company, which represents a lengthy and highly expensive procedure.

IP-related challenges in the case of Envirox™
A company called Oxonica bought a license from another company Neuftec. Oxonica allocated a team of nanotechnology scientists to further develop the technology. However, the original patent and licensing agreement soon became the subject of dispute between the two companies. Oxonica made discoveries which were outside the boundary of the original patent and hence refused to pay royalties for sales made from those. However, Neuftec did not agree. In the end, Oxonica lost the legal dispute to Neuftec. Full settlement was made to Neuftec by Oxonica, and then the latter was sold to another company.

Strict confidentiality measures

The hypothesis that ***any sensitive information on the innovation is never disclosed without a signed confidentiality agreement*** was confirmed.

Confidentiality measures in the case of Fiber Laser PFL-200
At early stages, the company did not have legal agreements with other parties such as research partners and suppliers. Most of the business engagements involved interpersonal relationships and friendship. However, in the later years, they started signing non-disclosure agreements (NDAs) while collaborating with partners or customers.

In case of Q.E.F. Epilepsy Bracelet, NDA is part of the producer's terms of delivery; it is also part of the terms of employment at the company. Similarly, for APADENT and APAGARD Nanohydroxyapatite Toothpaste, Silverlon Wound Care dressings T-Sight 5000 and Oxonica, NDAs were signed with the manufacturer. In case of DFB laser, NDAs were signed with buyers and suppliers. For NAO Robotics Platform, all members of the team signed NDA, but not the investors. The reason for that was suggested to be lack of background knowledge and interest for copying technical details from the investors' side.

Timing for choosing the IP strategy

A decision about how and when to commercialise the innovation to a large extent determines the choice of an IP strategy. When commercialising technology, the time dimension should never be ignored. ***Trying to make a deal too early is likely to lead to the situation when nobody wants to have a technology***. Trying to make a deal too late is likely to lead to the situation when the offer is not competitive anymore. The trick here is to be just-in-time[34]. The easiest way to be in-time is to build a relationship with a downstream acquirer in which they provide information about what they will be looking for and when. For this reason, initial deals are often as much or more about relationship building than they are about IP rights.

[34] Speser P.L. (2006) The Art and Science of Technology Transfer, John Wiley & Sons, Inc., Hoboken, New Jersey

Additionally, to convince a company or other party to invest in a technology, a return-on-investment (ROI) needs to be calculated. The return-on-investment is a threshold criteria for buying, licensing, or otherwise acquiring a technology. The ROI needs to be obtained in some period of time, usually 5 years. To find out what the period is for a company or an industry, experts and other knowledgeable people are often consulted[35].

Furthermore, clear agreements with industrial partners need to be made. Some good practices for making such agreements include the following[36]:

- Restricting the agreement to an academic chair or a defined number of people;
- Inventions in a certain field can, by chance, pop up at any place in the research organization (especially in universities, it is crucial to make arrangements with the group in question. If other groups come up with interesting results, they are not included in the deal);
- Restricting the agreement to a certain technology field; it is important to define as much as possible which technological area is subject to the arrangements;
- Restricting the agreement to a certain application or market field;
- Restricting the agreement in time.

3.2.11. Activity 5 Prototyping and industrial demonstration: processes for efficient manufacture and market delivery in the future

A prototype is a necessary prerequisite for a successful innovation. The potential buyer often does not fully understand the technology since it exists as a real, understandable thing only in the mind of the technology developer. Diagrams, equations, sample computer code and other technological information is not enough to adequately convey the technology. To understand a real technological concept, the buyer often needs to see the product that has the technology imbedded in it[37].

During the industrial demonstrator stage, the focus shifts to adapting the prototype for commercial exploitation. Creation of the processes required for efficient manufacture and market delivery of a commercial product based upon the prototype characterises innovation in the commercial stage. Innovative emphasis shifts from product function to process development and refinement. Process-focused innovations during this stage are likely to be radical rather than incremental, since

[35] Speser P.L. (2006) The Art and Science of Technology Transfer, John Wiley & Sons, Inc., Hoboken, New Jersey
[36] Tolfree D., Jackson M.J. (2008) "Commercializing micro-nanotechnology products", CRC Press
[37] Tolfree D., Jackson M.J. (2008) "Commercializing micro-nanotechnology products", CRC Press

commercial production of the prototype is often novel and will commonly require entirely new manufacturing and/or delivery processes[38].

The industrial demonstrator phase is particularly important for NMP products. ***Long-term reliability is essential for all miniaturised components if they are to be incorporated or embedded into products since failure usually means the replacement of the whole product***. For example, production and assembly methods for integrated circuits and MEMS systems make replacement of individual components or maintenance schemes too costly. No product will be able to retain its market credibility without total product reliability assurance. Therefore, design for reliability must understand, identify, and prevent failures before the manufacturing stage is reached. All possible failure modes in different environments must be thoroughly tested to ensure that failure model predictions are verified[39].

Active use of prototypes and proprietary control

We hypothesised that the prototype implies the product that has the technology imbedded in it. Additionally, ***the prototype stage is expected to involve proprietary control via patent or other IP protection mechanisms***.

The first hypothesis proved to be valid for all our cases. For example, in case of Fiber Laser PFL-200, a prototype represented a laser packaged in a box. Q.E.F. Epilepsy Bracelet went through a series of prototypes, with each new prototype being a slightly advanced version of the previous one. Sometimes prototyping referred not to the whole product, but also to its specific elements (in case of technically highly complex innovations). For example, in case of NAO Robotics Platform, several prototypes with different functionalities were incorporated in the design of the final product. A similar situation was observed in T-Sight 5000 case, where each component was tested as a prototype.

The second hypothesis on the proprietary control was supported as well. While some companies already had patents at the prototype stage (e.g., Fiber Laser PFL-200, NAO Robotics Platform), others worked with NDAs (e.g., Q.E.F. Epilepsy Bracelet, T-Sight 5000).

Contacts with customers during prototyping

Additionally, we hypothesised that ***the prototype stage involves contacts with customers and collaboration partners***. This hypothesis proved to be valid for all our cases except one (DFB laser), where no

[38] Underweiser M., Ludwin R.M., Ehrlich M: IBM – Understanding the Innovation Cycle http://www.thersa.org/__data/assets/pdf_file/0020/126542/IBMinnovationcyclesfinal.pdf
[39] Tolfree D., Jackson M.J. (2008) “Commercializing micro-nanotechnology products”, CRC Press

contact with customers or collaboration partners was established. In case of Fiber Laser PFL-200, the prototype was developed together with the University of Tokyo research lab which represented a potential customer. The company had a close contact with the university throughout the whole research phase. In case of Q.E.F. Epilepsy Bracelet, the initial prototype was constantly being improved based on customer feedback. NAO Robotics Platform had its first prototypes developed in-house, but those were already sold as products to the first customers (e.g., RoboCup), who in turn provided the company with extensive feedback for further improvements.

In-house prototyping activities

Prototyping micro-nano structured devices often raises challenges. Existing studies suggest that companies often form partnerships or strategic alliances with foundries or specialist providers for this purpose[40]. More and more companies realise the importance of the need for integrated solutions. As a result, the need for engineering simulation becomes a major factor to ensure innovation's and company's success. Therefore we hypothesised that, for prototype development, innovation developers form partnerships or strategic alliances with foundries or specialist providers. Interestingly, this hypothesis proved to be invalid for all cases except T-Sight 5000.

In case of Fiber Laser PFL-200, since the required materials for building the prototype were available in-house, no specific partnerships were made at this stage. Existing machinery that was bought for thin-films was put to use for the prototype generation of PFL-200. Similarly, for Q.E.F. Epilepsy Bracelet, NAO Robotics Platform and Silverlon Wound Care dressings, ***prototypes were developed and assembled in house***.

Prototyping to prevent failures in manufacturing

We hypothesised that an industrial demonstrator allows to understand, identify, and prevent failures before the manufacturing stage is reached. At this stage, ***possible failure modes in different environments are thoroughly tested to ensure that failure model predictions are verified***. We were able to find evidence for the validity of this hypothesis in several cases (e.g., Q.E.F. Epilepsy Bracelet, APADENT and APAGARD Nanohydroxyapatite Toothpaste, Envirox™ and Advanced Marine Coatings).

[40] Tolfree D., Jackson M.J. (2008) "Commercializing micro-nanotechnology products", CRC Press

3.2.12. Activity 6 Product trials and sales: clear naming and framing

The competitive landscape during the commercial stage is characterised by product variation between competing firms, each focused on bringing to market their versions of the product. Since product differentiation in terms of function and cost may well determine the market winners, the commercial stage represents the peak of private value for the innovation timeline. Firms competing for market advantage are likely to rely on closed development and proprietary intellectual property protection mechanisms to garner and sustain market advantage. Nevertheless, as competitive firms begin to increasingly make innovative products available to the public at competitive prices, the net benefit to the public from such innovations begins to rise significantly[41].

Clear naming

According to the literature, ***a catchy and easy-to-understand name is the minimum amount of positioning needed to make the product recognisable for the very first customers***. Customers usually do not buy what they cannot name, nor do they seek out the product unless they know what category to look under. Additionally, customers will hardly buy something until they know who is going to use it and for what purpose. Finally, customers cannot know what to expect or what to pay for a product until they can place it in some sort of comparative context[42].

Consequently, we hypothesised that when introduced to the market, successful innovations are clearly named and framed. ***For some cases, this hypothesis proved to be valid, while others did not pay much attention to the selected name and used standard company's acronyms, codes or brand names***.

The following cases involved selection of a catchy name. NAO Robotics Platform got its name for the key character Neo from Matrix movie (at that time, an absolute hit in the cinemas around the globe). Initially, NAO was a code name within a company, but it soon became an official name of the product. In case of Nanohydroxyapatite Toothpaste, the selected names are APADENT and APAGARD. Much attention was paid to the names. They reflect the vision of the company to create natural products that promote health and natural healing. For Envirox™, the name was developed by the development team. It is a combination of environment issues (Envir) and Oxford (ox), where the company was based.

[41] Underweiser M., Ludwin R.M., Ehrlich M: IBM – Understanding the Innovation Cycle http://www.thersa.org/__data/assets/pdf_file/0020/126542/IBMinnovationcyclesfinal.pdf

[42] Moore G.A. (2001) *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers*, HarperCollins Publishers

Clear positioning on the market

Additionally, we hypothesised that positioning of successful innovations specifies who it is for and what it is for. This hypothesis proved to be valid for all the analysed cases. Positioning of successful innovations specifies their R&D aspects and potential applications, key product features and direct customer benefits. In many cases, this information is available online (e.g., Envirox™, Advanced Marine Coatings).

Complementing technological innovation by social innovation

NMP innovations are innovations of potentially disruptive nature, i.e., they often offer radically new ways of doing things and are initially too unknown and sophisticated for the majority of their potential customers. Consequently, NMP innovations are much more than just technological innovations. NMP innovations are associated with a wide range of social complexities that need to be taken into account when developing marketing strategies for such innovations. These social complexities among others include the following:

- the need to 'prepare' the market mentally for the arrival of the innovation;
- the need to educate the users with regard to how to exploit the innovation;
- the need to exploit new communication channels with potential users;
- the need to develop new business models that best reflect the nature of the innovation (including new type of after-sales services).

Social innovation in the case of APADENT and APAGARD Nanohydroxyapatite Toothpaste

APADENT and APAGARD Nanohydroxyapatite Toothpaste was the first nanotechnology toothpaste in the world. In the beginning, the product was positioned as having anti-caries and remineralising benefits. The marketing was targeted at dentists and related actors in the oral care sector. However, despite or possibly because of its technological newness the product did not attract much interest from its potential customers. Consultation rounds with customers revealed that anti-caries properties of the toothpaste were not perceived as valuable enough to make a switch to this new unknown product. The aspect that proved to sufficiently trigger customers attention referred to the whitening properties of the toothpaste. After it was discovered, the company quickly repositioned the product and launched its first TV commercial "I love white teeth," which featured well known actors. It was a success resulting in higher sales. Company's ad phrase in the commercial "A celebrity's teeth are his life!" became a national sensation.

Social innovation in the case of MakerBot
MakerBot was the first company to ever do crowdsourced manufacturing. The concept of crowdsourced manufacturing implies that instead of having a centralised factory that produces parts and then distributes them to the people who want them, individuals have the tools they need to build what they want and distribute it without a central hub. MakerBot was unable to keep up with the demand for their 3D printer, so they have turned to their customer base and asked them to manufacture some of the parts (pulleys) for them using the existing 3D printers. The owners of the 3D printers were thus helping MakerBot with producing new 3D printers. The current innovation did not require any special funding. It implied developing a user-friendly downloadable design of the pulley, posting an announcement on the blog and then performing the quality check of received pulleys.

Consequently, ***for KETs in general and NMP innovations in particular, there is a need to embrace a broader concept of innovation, including its non-technological aspects, i.e. social innovation***[43]. Social innovation goes hand in hand with NMP technological innovation, and proves to be decisive for successful market entry and commercial growth.

Differentiation from competitors

We also predicted that when targeting a mainstream market, the innovation's positioning demonstrates how this innovation is different from the competitors. This hypothesis proved to be valid for most of the analysed cases (e.g., Envirox™, Fiber Laser PFL-200, Advanced Marine Coatings) except T-Sight 5000. In some cases, companies simply claimed that their product is of unique nature and that no comparable options are currently available on the market (e.g., Q.E.F. Epilepsy Bracelet; DFB laser). Some companies went even further, and emphasised the uniqueness of their product by high price strategy. For example, APADENT and APAGARD Nanohydroxyapatite Toothpaste was kept in a special box at the pharmacy store, and the box read 'The most expensive toothpaste in the world". In some cases, the product needed to be brought to the customers to demonstrate the features in real, otherwise the customers refused to believe it is true (e.g., NAO Robotics Platform).

Using the 'right' communication channels

Finally, we expected that in case of successful innovations, the selected communication channels were the ones that were likely to be monitored by potential buyers (e.g., specific websites, magazines, newsletters). This hypothesis proved to be valid for all our cases. The selection of a communication channel depends on the nature of product and type of clients that are targeted.

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[43] See also EC (2011), *Green paper on a common strategic framework for EU research and innovation*: Analysis of public consultation, p.24

Innovation’s diffusion patterns depending on its category and complexity

Distribution of NMP products is often more complex than most technology entrepreneurs are able to imagine. Typically, technology products are not sold to consumers. They are sold to other manufacturers who sell to consumers[44].

Different cases demonstrate different diffusion patterns. ***Dissemination channels, pricing and marketing strategy differs depending on the product category and its technical complexity***. While highly complex NMP products are typically sold by means of physical presentations and demonstrations at client’s premises or during trade shows, mainstream-market oriented products are promoted by means of TV commercials and smart merchandising.

Innovation’s diffusion in the case of Epilepsy Bracelet
The company first tried to sell the product directly to households, which proved to be an unsuccessful experience given relatively high product costs and a lack of clarity with regard to who should pay for the product: insurance companies or people themselves. The company thus experienced difficulties with selling the product to the first clients, and several orders were cancelled due to the reasons mentioned above. Then the company turned to the Epilepsy Association in order to start selling products to institutions rather than end-users. There was a clear need to demonstrate the product and its characteristics to the buyer. The price issues could hardly be solved due to a small-scale production, and large volume orders were necessary in order to be able to lower the price. However, no buyers wanted to place large orders while the price was so high. These factors led to a closed loop from which the company still did not manage to get out. Nevertheless, the product is associated with a large potential client base, and additional efforts are needed from the distribution side to ensure several ‘big’ deals for the company to acquire sufficient client base.

Innovation’s diffusion in the case of NAO Robotics Platform
The innovation was diffused to technology enthusiasts and early adopters in a couple of years. The first end-users were identified with the help of the RoboCup[45]. Being selected for the RoboCup got the company in touch with potential users all over the world. Due to the high level of software engineering skills required to understand NAO, it has not yet been diffused to the early majority or the mainstream market. They currently have a developer program running with the key goal to develop applications to make using NAO less complicated. The company identified their “in between” market, i.e. the market between academics and households, to be the use of robots for professional applications (e.g., hospitals, taking care of children, taking care of elderly people). Robots can, for example, welcome people in companies. The robot could lead the way, register the visitors, provide information, etc. This is viewed as a big potential market.

[44] Tolfree D., Jackson M.J. (2008) “Commercializing micro-nanotechnology products”, CRC Press
[45] RoboCup is an international robotics competition founded in 1997. The aim is to develop autonomous soccer robots with the intention of promoting research and education in the field of artificial intelligence. The name RoboCup is a contraction of the competition's full name, "Robot Soccer World Cup", but there are many other stages of the competition such as "Search and Rescue", "RoboCup@Home" and "Robot Dancing".

Innovation's diffusion in the case of APADENT and APAGARD Nanohydroxyapatite Toothpaste

The first customer was a retail shop. The price of the product was several times higher than of a 'traditional' toothpaste. The product was accompanied by detailed descriptions, and it was possible to try it out through a sample. The product was positioned as "the most expensive toothpaste" helping to treat medical problems related to teeth, but such positioning did not get the company much further, and the level of sales was low. The next step that the company made was cutting down the price by half just to boost the sales. Such strategy was accompanied by a massive advertising campaign on TV. This time, the toothpaste was not positioned as the one helping to deal with teeth health issues, but as a teeth whitener. The latter idea was developed based on the feedback from the first customer base. Such marketing tactics proved to play a crucial role in further diffusion of the product.

Members of product design team or technical experts as the first buyer

We hypothesised that ***in large companies, the first buyers can be found in the advanced technology group or similar departments, whereas in smaller companies, those are likely to be members of a product design team or technical experts***. In general, the hypothesis proved to be valid, with a few exceptions where products referred to a specific application area (e.g., APADENT and APAGARD Nanohydroxyapatite Toothpaste, for which the first buyers were small retail pharmacies; Silverlon Wound Care, for which the buyers were found within hospitals).

The most popular communication channels were reported to be the following:

- ***Social networks, personal relationships with potential customers and on-site demonstrations*** (e.g., Fiber Laser PFL-200; Q.E.F. Epilepsy Bracelet; NAO Robotics Platform; APADENT and APAGARD Nanohydroxyapatite Toothpaste; Silverlon Wound Care dressings; Envirox™; Advanced Marine Coatings);
- ***Internet marketing campaigns*** (e.g., DFB laser);
- ***Trade shows and fairs*** (Silverlon Wound Care dressings; Envirox™);
- ***Existing customers*** (e.g., T-Sight 5000).

A trust relationship between the company and its early customers

Building a relationship of trust between the company and its early customers was identified as a key success factor for some of the cases. Early customers are often unfamiliar with the product and may feel reluctant to bet their resources on it. ***Building a relationship of trust turned out to help take away some of the scepticism, thus helping with the diffusion of the innovation***. In the case of NAO Robotics Platform, early customers were sceptical of the product. Personal relationships based on trust were key to convince them to try the product.

Importance of a thrust-based relationship was also found in the cases of Envirox™, Advanced Marine Coatings, tripleO and Silverlon Wound Care.

Value-based pricing strategy

We hypothesised that selling the innovation to early adopters allows generating first considerable financial results. Additionally, we predicted that the strategy of value-based pricing is applied (highly priced, includes the need for special services). These hypotheses proved to be valid for most of the cases. In some cases, selling the product to early adopters allowed to sustain business rather than to generate big profits (e.g., Fiber Laser PFL-200; Q.E.F. Epilepsy Bracelet; APADENT and APAGARD Nanohydroxyapatite Toothpaste). A value-based pricing strategy was adopted by, for example, Envirox™. In some cases, companies offered after-sales service to which extra charges apply (e.g., Advanced Marine Coatings). However, in other cases, the product had to be made affordable to penetrate the market (e.g., NAO Robotics Platform).

Offering comparative business advantage

We also hypothesised that ***successful innovations offer their early adopters a clear comparative business advantage, e.g., lower product costs, faster time-to-market, more complete customer service***. This hypothesis was also confirmed by most of our cases. For example, in case of Fiber Laser PFL-200, the company positioned their product as the cheapest simple, stable and small laser. They emphasised the fact that PFL-200 can have numerous applications, either as a stand-alone product or as a part of a system. In case of Q.E.F. Epilepsy Bracelet, an existing solution did not exist on the Dutch market, hence the benefits were quite unique: alert message to caregivers in case of an epilepsy attack by wearing a simple wristband. For NAO Robotics Platform, existing solutions were not nearly as sophisticated, even in some higher price ranges. Also in case of APADENT and APAGARD Nanohydroxyapatite Toothpaste, later on the product was offered at a relatively lower price while it offered functional superiority. Envirox™ and Advanced Marine Coatings offered their customers significant fuel savings.

Breakthrough on the market

Based on the literature, we also predicted that ***early adopters give the innovation its first big break***. This hypothesis was confirmed for most of our cases. For Fiber Laser PFL-200, it helped with improving the product in terms of size, stability and other criteria. This opened up new areas of applications. In case of Q.E.F. Epilepsy Bracelet, fine-tuning the device with the first client resulted in more sales. In case of NAO Robotics Platform, securing the RoboCup accelerated the innovation and diffusion cycle of NAO. Similar situations were observed in the cases of Envirox™ and Advanced Marine Coatings.

Revising marketing strategy when entering a mainstream market

The hypothesis that ***the innovation's transition from an early market to a mainstream market requires a complete revision of the market strategy (positioning, segments, pricing etc.)*** proved to be valid for most of the cases. In case of Fiber Laser PFL-200, the strategy of the company changed from selling only to R&D labs to industrial players. In case of NAO Robotics Platform, by developing enough high quality apps to make NAO work without need to program it, the company hopes to provide access to the mainstream market in the future. For APADENT and APAGARD Nanohydroxyapatite Toothpaste, CEO collected feedback from the early customers and revised the strategy from disease-preventing to a whitening toothpaste. Aggressive marketing efforts resulted in unprecedented growth in sales. In case of Envirox™, the company realigned its strategy in the later years to focus only on bus segment. Since there major customer was in bus industry, it helped them to establish a foothold in that segment.

In two of the analysed cases, however, the marketing strategy was not significantly changed. For Silverlon Wound Care dressings, after fours year of sampling and evaluation, the company was attracting paying customers, mostly physicians within hospitals. They were attracted through superior clinical results of the early adopters in the first segment. However as sales volumes rose, distribution took place through agents. Also the product range was expanded to address different markets. Similarly, in case of DFB laser, the main elements of the strategy have not been altered. However, through incremental innovation, the application range of the lasers widened and therefore more potential customers and application segments were reached.

Targeting specific market niches

We predicted that ***the innovation's transition from an early market to a mainstream market can be achieved by targeting a specific niche market where the innovation can force its competitors out of the market niche, and then use it as a base for broader operations***. Additionally, it was expected that a high-tech market for an innovation is developed gradually, at certain points of time focusing on specific types of technology adopters: focusing first on innovators, growing that market, then moving on to the early adopters, growing that market, and so on, to the early majority (and possible late majority and even to the laggards).

These hypotheses too proved to be valid in most of our cases. Successful NMP innovations targeted specific market niches, and in case those niches were not initially identified, it proved to be difficult to become commercially successful unless niche strategy was developed.

3.2.13. Activity 7 Industrialisation: searching for cost-efficient solutions

This activity implies a shift toward real-life applications, as well as the increasing demand from industry (scaling-up), growing customer base and first licensing agreements.

We hypothesised that ***upscaling NMP products is often problematic, costly and requires significant investments***. This hypothesis proved to be valid for most of our cases except NAO Robotics Platform. In that case, the short-loop process is one of the key success factors and one of the reasons why they were able to make quick progress.

In case of Fiber Laser PFL-200, the number of lasers produced was small. It is not cost-effective to establish a production line. Rather, they build lasers by hand. In case of Q.E.F. Epilepsy Bracelet, to sell more products, they would need to lower the price, which can be the result of economies of scale. For economies of scale, however, the company would need to upscale production, but that provides the risk of having an obsolete stock of inventory. Similarly, in case of APADENT and APAGARD Nanohydroxyapatite Toothpaste, the blocking factors at the initial stage of product development were mainly technical and financial.

Some industrialisation-related key success factors can be identified based on the sample of analysed cases:

- Careful selection of an external manufacturing company which could provide detailed feedback on product design (e.g., Q.E.F. Epilepsy Bracelet; Envirox™);
- Working with small-size partners allows for making decisions quickly (e.g., APADENT and APAGARD Nanohydroxyapatite Toothpaste);
- Working with used equipment through Internet auctions (e.g., DFB laser).

3.2.14. Activity 8 Managing innovation: connected and free thinking

Innovation management refers to the central activity of the innovation cycle and is linked to all other elements. Without proper management processes, it is not possible for R&D&I to be efficient. Innovation management includes a set of tools that allow entrepreneurs, managers and engineers to cooperate with a common understanding of goals and processes. To succeed in it, an understanding of both the market and the technical problems is needed. By creating multi-functional development teams, both dimensions can be covered.

Multidisciplinary teams

The NMP product design engineers must work closely with process, equipment, manufacturing, assembly, and facilities engineers. This team approach is crucial for designing an optimised product. There is a lack of standard, off-the-shelf fabrication and measurement equipment, parts, connections, packaging, processes, and micro-assemblies. Therefore, ***product design, process development, manufacturing, assembly, and unique facility requirements must be considered jointly when designing NMP products***. Companies that produce successful products typically practice the integrated team approach, mainly to develop processes and equipment for manufacturing, assembly, and measurement[46].

NMP start-ups are often based on a technology platform that is composed of IP generated by a team of scientists who are interdisciplinary in nature with no business strategy, focus, or management structure. The team is composed of highly respected academic scientists who can ensure sources of funding through research contracts. In their initial stages, these companies team up with established companies to help them validate products, provide a channel for marketing and selling products, and provide expertise in manufacturing[47].

No thinking in terms of silos

As hypothesised, ***managers of successful innovations do not think in terms of silos***. Managers are reported to have granted much freedom to the team to conduct research and develop the innovation (e.g., Fiber Laser PFL-200; NAO Robotics Platform; APADENT and APAGARD Nanohydroxyapatite Toothpaste; Envirox™). In case of Q.E.F. Epilepsy Bracelet, there was even no track of costs of the innovation project. There was no fixed budget and there were no financial commitments. It was purely a matter of "Do we want to develop this product?".

Openness for ideas from outside

We also predicted that ***managers of successful innovations are open for ideas from outside (open innovation concept)***. This hypothesis is particularly true for NAO Robotics Platform. They welcomed new ideas, and still do by stimulating the research community to develop new solutions. They made NAO more open source starting from 2011.

[46] Tolfree D., Jackson M.J. (2008) "Commercializing micro-nanotechnology products", CRC Press
[47] See also Tolfree D., Jackson M.J. (2008) "Commercializing micro-nanotechnology products", CRC Press

Engagement of diverse stakeholder groups

Successful NMP innovations imply the engagement of diverse stakeholder groups:

- ***Actors of the market***: NMP is fast becoming an important business area for companies in a diverse range of industries. It is expected to have a major influence on virtually all sectors where materials play a role, such as aerospace and defence, electronics, energy, life sciences and healthcare, textiles, environment, water, food, construction, consumer goods, household care, security, automotive, chemicals and coatings. Actors of the market can thus be found in a variety of sectors. These can be directors or managers (R&D, HR, Marketing etc.) of key companies that have implemented the technological innovations. These can be large companies, but also SMEs, and in some cases consumers.

- ***Actors of the value chain***: value can be added to the NMP value chain at three different stages: at the stage of the materials, intermediates and end-products[48]. These can be investors, either of private or public origin, various suppliers, but also business and legal advisors that add value along the chain.

- ***Partners in research projects***: other than the value added through the abovementioned investment in the value chain, an entrepreneur may engage other stakeholders in the development of the innovation, thus combining a variety of skills and experience. These stakeholders come from the world of academia, other research organisations or industry (both large companies and SMEs) and include managers or researchers of corporate laboratories, research centres or universities.

- ***Public actors***: we can identify several types of organisations that are of importance to NMP innovations. Some examples are ministries of education, science, research; ministries of economy, industry and trade; ministries of public health; ministries of environment; regulators and standard bodies. This list still leaves room for several types of regional, national and European advisory organisations and boards on, for example, innovation, science, ethics, R&D, etc.

Maintaining relations with all market players

Based on the literature, we suggested that ***a key to success on the high-tech market is to build and manage relationships with all the members that form the market, not just the most visible ones***. In

[48] "Sizing Nanotechnology's Value Chain", report by Lux Research

particular, it means establishing formal and informal communications not only with customers, press, and analysts, but also with hardware and software partners, distributors, dealers, VARs [value-added-resellers], system integrators, user groups, vertically oriented industry organisations, universities, standards bodies, and international partners[49].

This hypothesis proved to be valid for some of the analysed cases. In case of Fiber Laser PFL-200, the company founders mobilised their network of different research labs and universities (organisations identified as laser's potential customers). In case of Envirox™, the company also uses networks with diverse actors. Apart from customers, manufacturing partners, the company is a member of various associations such as Nanotechnology Industries Association (NIA), Knowledge Transfer Network (KTN) in UK, Low Carbon Vehicle Partnership (LowCVP), and trade association of the UK bus industry (CPT). In this way, the company claims to establish credibility in the industry. It is seen as a visible and respectable member of the organisations. By joining the bus industry organisation, consisting of big transportation companies, the company tends to gain visibility in the sector. In other cases, the companies did not yet succeed to establish relationships with a broad range of parties on the market.

Building tactical alliances with other organisations

Partnering with others often makes it more likely that the innovation will sell. It can also lead to cost reductions by:

- enabling the partners to leverage economies of scale and scope or network economies;
- offering learning curve advantages;
- guaranteeing access to supplies or the ability to drive supply costs down by buying in volume;
- giving access to previously expensed or depreciated facilities and equipment that still have productive life left;
- offering internal capital at below market rates; and so on[50].

Our analysis confirms that NMP product innovations imply intensive cooperation with a wide range of external stakeholders: universities and specialised research centres, software developers and designers, suppliers and manufacturers, as well as user community. The latter proves to be particularly important for technically highly complex innovations not targeting the mass market, but specific customer segments (see, for example, NAO Robotics Platform). Interestingly, several cases mentioned unsuccessful experiences in the attempt to collaborate with large

[49] Moore G.A. (2001) *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers*, HarperCollins Publishers
[50] Speser P.L. (2006) The Art and Science of Technology Transfer, John Wiley & Sons, Inc., Hoboken, New Jersey

companies. The latter were reported to be highly demanding in terms of price and liability, and often not interested in sharing information with high-tech SMEs. In many cases, collaborations with universities (sometimes foreign universities) are reported to be prominent. For example, in case of Advanced Marine Coating, the company quickly realised that weather conditions in Norway were a stumbling block to conducting field trials in Norway throughout the year. Therefore they partnered with National University of Singapore (NUS) as Singapore offered a warmer test bed throughout the year. This partnership has accelerated the development of the technology. Some cases, however, reported that no tactical alliances were formed (e.g., Fiber Laser PFL-200; Silverlon Wound Care dressings; DFB laser).

Key barriers

The following key barriers can be identified regarding innovation management:

- Lack of clear vision from the CEO's side which translates to the team (Fiber Laser PFL-200);
- Time management and the need to dedicate a significant amount of time to the customers' requests (i.e., adjusting the product to the customers' needs; e.g., NAO Robotics Platform);
- Rotation of managers (e.g., APADENT and APAGARD Nanohydroxyapatite Toothpaste).

3.3. Short development cycles and first-to-market strategies

Successful NMP innovations aim at reaching the market as quickly as possible, and often are the first ones on the market in their field.

Most NMP cases demonstrated a clear ***desire to quickly reach the market*** which can only be possible with a short development cycle. Many of the analysed companies were the first in the world to offer a certain product/material or organise a business in a new way. Initially, we hypothesised that the total innovation cycle from research to the market for NMP innovations takes about 10-20 years. The analysis showed that the total duration of the innovation cycle proves to depend on the sector rather than on the technical complexity of the innovation. Several innovations from the sample managed to reach the market within a couple of years. Interestingly, these innovations demonstrated high technical complexity[51]. For innovations related to the medical sector, the regulatory environment was reported to serve as a key reason for a delayed market entry (15-20 years in total). In general, there

[51] Technically complex innovations usually are based on the results of previous basic and/or applied research which may take up to several decades. Claims about short time-to-market of such innovations should therefore be made with great caution.

is a clear trend that companies try to introduce the NMP innovations to the market as soon as possible. However, ***in some cases, especially if the product falls under the category of medical devices, equipment or treatment, time-to-market significantly increases because of regulatory requirements***.

Ability to provide a highly complex product for a competitive price, and being the first to do so is particularly relevant for companies that developed a microelectronics-related product. Some of the companies in our sample already set clear goals from the beginning to be the first to come up with a highly complex product while offering it for a competitive price. Being the first has the obvious example of potentially capturing the market. In the case of NAO Robotics Platform, it also helped them to bring the product quickly to the market to improve it together with the end-users. In a market where more similar product already exists, the first product on the market often needs to be more sophisticated. Also in the case of NAO Robotics Platform, they set the goal from the start to offer the product at competitive prices. A similar observation can be found in the case of Q.E.F. Epilepsy Bracelet, where the company was committed to engineer a complex and high-quality solution for an affordable price.

The analysis clearly demonstrated that the teams were open towards the ***unconventional ways of doing business***, furthermore, they were intentionally looking for new ways of organising the production process, marketing, distribution etc. The ambition was to offer the world something it has never seen before, while it clearly reflects the needs of the modern and future society. The innovations were designed is such way that it was ***easy to respond to the rapidly changing environment and to incorporate user feedback***.

3.4. Human factor: charismatic leaders and highly motivated teams

Our analysis confirmed that some of the key factors determining the success of the innovation refer to so called human factors or people standing behind the innovation.

Charismatic leaders

Successful NMP innovations are typically driven by charismatic leaders.

Charismatic people in the team (in the role of managers/leaders) represent a necessary prerequisite for successful progression of NMP innovations. Such people typically demonstrate ***clear vision and articulation, sensitivity to the environment, sensitivity to needs of the team, personal risk taking, and unconventional behaviour***.

Charismatic leaders are able to use their personal charm to get things done, and they are acting as role models to their team members. The analysed cases suggest that such charisma can be helpful not only for motivating individuals to accomplish some extraordinary tasks, but also to raise funds from external investors.

With NAO Robotics Platform, the CEO had a strong vision and was considered to be charismatic. With years of high level experience in banking, he also acquired excellent negotiation skills and was well equipped to attract the necessary funding. In the case of APADENT and APAGARD Nanohydroxyapatite Toothpaste, we also observe a highly charismatic leader. Moreover, his willingness to take big financial risks to support his belief, and his ability to convey his enthusiasm about the project to others were identified as key success factors in that case. In case of DFB Laser, similar situation was observed. His influence was considered to be of high importance throughout all stages of the innovation cycle. In the tripleO case, we identified a leader with a strong vision, paired with strong negotiation skills. He was able to convince the sceptical aviation industry of his product's worth, while strictly refraining from negotiating on price.

Highly motivated teams

Successful NMP innovations rely on enthusiastic, ambitious and highly skilled teams driven by intrinsic motivation.

Additionally, ***successful NMP innovations are typically developed by enthusiastic, ambitious and highly skilled teams, with true passion for what they are doing***. These people often find the technically challenging nature of the innovation a nice change of work from more standard product development within the company. They are typically genuinely interested in the idea itself. Oftentimes we were able to detect almost an altruistic desire to make the world a better place, and, in case of small companies, examples were found when company's profit was spent exclusively on improving the innovation even further.

For example, for Q.E.F. Epilepsy Bracelet, it was found that the team enjoyed developing the product as the technically challenging nature of the innovation was viewed as a nice change of work from more standard product development within the company. They were also interested in the idea itself. Although the team had a high level of education and were highly skilled, the innovation itself required knowledge in many different fields. Due to their enthusiasm, ambition and skill they overcame the technical challenges and quickly engineered a prototype. In case of NAO Robotics Platform, having a highly enthusiastic, ambitious and highly skilled team was key to the development of the product. They set ambitious goals, particularly securing the RoboCup standard platform deal, which they could only meet by being passionate about the work they were doing while being highly skilled.

Three possible scenarios can be observed with regard to the skills of the team in the beginning of the commercialisation path for NMP innovations. First, ***the innovation is driven by a person/group of persons with a strong technical background***. These people typically are engineers and lack the necessary skills to start a business. Once the decision is made to commercialise the innovation, these people typically join forces with market experts, i.e., people with a good knowledge of business development, marketing, finance, HR and other relevant issues. Second, ***the entrepreneur sometimes has a business background with a relatively limited technical background***. However, there is a clear ambition to commercialise a high-tech innovation, and then the forces are joined with people having a strong technical background and/or idea that can be commercialised. The final scenario implies ***an entrepreneur combining technical and business background simultaneously***; however, this model only proves to be working if the company is at its very beginning. Once the volume of company's operations grows, there is an inevitable need to hire more people and to go for specialisation (i.e., creating specialised departments such as Production, HR, Marketing and PR etc.).

3.5. Differences and similarities between EU and non-EU cases

In the current sub-section, we analyse the differences and similarities between the EU and non-EU cases. As presented in Chapter 2, the analysed sample contains 21 case from Europe, 5 cases from East Asia and 4 cases from North America. Consequently, the conclusions presented in this sub-section should not be viewed as a result of a quantitative exercise, but rather a thorough qualitative examination of a limited number of cases.

Hardly any differences were detected between the successful cases from different world regions with regard to both micro- and macro-level factors. There is a set of common trends that can be observed among the majority of the global innovation showcases despite their geographical location.

For the purpose of this analysis, we first split all the relevant factors into two major groups: *micro-level* factors and *macro-level* factors. The first group refers to the aspects related to the internal influence on the development of the innovation in question. This group includes factors like team and skills, market knowledge and strategy, funding etc. The second group refers to factors that have an external influence on the success of the innovation. This group includes factors related to regulation and standards, public procurement, market developments etc.

Micro-level factors

Interestingly, when comparing global successful innovations from different regions, ***hardly any differences can be observed with regard to the micro-level factors***. There is a clear trend across all cases from Europe, East Asia and North America of having highly motivated multidisciplinary teams led by charismatic leaders, having top achievers on board with almost an altruistic passion about their work, with a general team spirit being focused on 'making this world a better place'. The successful innovation management teams from all regions aim at short innovation development cycles and first-to-market strategies complemented by active early engagement with end-users to attain feedback and to develop an even more advanced version of the product. Finally, despite a common perception that it is much more difficult to attract VC funding in Europe than in North America, our analysis does not confirm it. The study shows that EU cases with leaders having access to strategically important networks of investors and thoroughly developed business plans (including rigorous competition analysis, feedback from end-users at early stages, well thought through positioning and pricing strategy etc.) in general do not face considerable difficulties when trying to raise VC funds (see, for example, cases of NAO Robotics Platform, Advanced Marine Coatings, and Resteel).

Existing studies report various cultural differences with regard to entrepreneurship between Europe, East Asia and North America[52], pinpointing issues like preference for self-employment, risk-aversion, availability of finance etc. However, the current study hardly detected any differences related to entrepreneurial culture between different regions. It does not yet mean that these differences were simply overlooked. In the context of this study, ***the analysis exclusively focused on globally successful innovations that implicitly suggests the presence of a certain set of characteristics that are common at the global level and thus spread beyond the borders of their own regions***. Consequently, globally successful NMP innovations may have more in common than previously thought (a comparison can be made here with athletes who win the Olympic Games while coming from different regions of the world). The analysis of less successful innovations and/or innovations not yet present at the global level is more likely to spot the differences between cases from different regions, and it can be a promising avenue of research for future studies.

[52] See, for example, the results of the Flash Eurobarometer "Entrepreneurship in the EU and beyond" available at http://europa.eu/rapid/press-release_MEMO-10-232_en.htm

Macro-level factors

As for the macro-level factors, some differences between world regions were identified. The differences, first of all, refer to the way the issue of technology transfer is approached in different regions. ***"European model" of technology transfer*** represents a top-down approach. Governments tend to directly engage in the establishment either by financing and/or legislating of particular types of Technology Transfer Offices (TTOs). The form of incentives for public research organisations to engage in technology transfer is expected to affect not only the likelihood and efficiency of technology transfers, but also its orientation and the channels used for this purpose[53].

The ***"United States model"***, in turn, follows a bottom-up approach. Policy focus there lies on creating requirements and incentives for public research organisations which stimulate them to intensify their commercialisation efforts. Public research organisations are completely free to choose the form, strategies and also the types of TTOs they view as most appropriate under prevailing circumstances. Historically, US universities have closer relations to industry than their European counterparts, and a larger share of their funding comes from private sources[54]. Additionally, several references were made to the Small Business Innovation Research (SBIR) program as best practice in the field of supporting young technology companies in the United States.

SBIR aims to encourage domestic small businesses to engage in Federal Research/Research and Development (R/R&D) that has the potential for commercialisation. Through a competitive awards-based program, SBIR enables small businesses to explore their technological potential and provides the incentive to profit from its commercialisation[55]. SBIR was launched in 1982, and is suggested to be the world's largest seed capital program for science and technology businesses[56]. Some of the most innovative United States companies have received early stage financing from SBIR, including Apple, Compaq and Intel. ***A key feature of the programme refers to the absence of a requirement of matching funds from the company's side which is often beyond the means of start-ups and small businesses, i.e., the program implies 100% funding plus a small profit element***.

[53] See also "Monitoring and analysis of technology transfer and intellectual property regimes and their use", 2009 Expert Group on Knowledge Transfer Report, DG RTD

[54] See also "Monitoring and analysis of technology transfer and intellectual property regimes and their use", 2009 Expert Group on Knowledge Transfer Report, DG RTD

[55] http://www.sbir.gov/about/about-sbir

[56] Connel D. (2006) "Secrets" of the World's Largest Seed Capital Fund: How the United States Government Uses its Small Business Innovation Research (SBIR) Programme and Procurement Budgets to Support Small Technology Firms", Centre for Business Research, University of Cambridge, available at http://www.cbr.cam.ac.uk/pdf/SBIR%20Full%20Report.pdf

Universities in Asia in recent years have advanced their rules for research results and Intellectual Property Rights and implemented patent legislation. A clear and clean patent is considered as the essential element for technology transfer. Nowadays, Asian countries are reported to have an Intellectual Property system that responds to global demands and meets international standards.

One Asian case from our sample (Ultra Compact Femtosecond Fiber Laser PFL-200) signalled ***patent filing issues in Europe for non-European innovations*** (i.e., long delays, high level of bureaucracy, high costs), while no issues were faced when doing the same in Japan and the United States. The company reported to be forced to hold back its patent filing. Eventually, they decided not to file it in Europe at all. It is important to mention, however, that the European patent system is characterised as being cumbersome and expensive also by European cases.

One American case (Silverlon) emphasised the ***role of pre-commercial public procurement in the success of innovation in the United States***, and specifically the engagement of the U.S. Army in testing during the Iraq and Afghanistan wars, and then massively buying the final product.

Both European and non-European cases report facing ***difficulties when trying to get an approval under the CE regulation***[57] (for example, Q.E.F. Electronic Innovations Epilepsy Bracelet, Silverlon). The process of getting an approval is reported to include several long delays that are suggested to be caused by lack of incentives for the administering parties to deal with an application in an efficient way, as well as potential conflicts of interest since the evaluators are themselves private companies (although they are overseen by government bodies).

When entering the global market, the cases report ***the need to deal with cultural differences and language barriers with other regions of the world***. These differences are suggested to be particularly considerable between Europe and Asia (see, for example, the case of NAO Robotics Platform, where they were forced to fully subcontract distributors for the Asian region).

Finally, cases from all regions emphasise ***the role of regulation*** in the development of their innovations. While sometimes regulation serves as a catalyst for a quick market entry, in most cases it is reported to be one of the key barriers. For example, in case of Silverlon (United States), legislation during the development phase of the product was reported to be favourable for experimenting with the Silverlon products. At the same time, in case of Envirox (Europe), regulation discourages massive usage of

[57] Directive 93/68/EEC, CE marking is a mandatory conformity mark for products placed on the market in the European Economic Area (EEA). With the CE marking on a product, the manufacturer declares that the product conforms with the essential requirements of the applicable EC directives.

the product in the United States. Environmental Protection Agency (EPA), a regulatory body of the United States, has indefinitely delayed the use of the product for U.S. highways. Regulators are reported to be cautious about the use of nanotechnology.

In Europe, eco-friendly NMP innovations are reported to be well supported by regulation (see, for example, the case of Advanced Marine Coatings). Other cases report some barriers posed by regulation. For example, European environmental legislation aims at banning certain semiconductor materials which contain arsenic from the European market, which is highly unfavourable for the DFB laser case. Similar developments were detected in East Asia; however, some cases report that the regulation about public safety is not yet fully developed in some Asian countries (e.g., Taiwan).

To conclude, hardly any differences were detected between the successful cases from different world regions with regard to both micro- and macro-level factors. ***There is a set of common trends that can be observed among the majority of the global innovation showcases despite their geographical location***. At the micro-level, those trends among others include highly motivated teams and charismatic leaders, active early engagement with end-users and good access to private funds. At the macro-level, the role of regulation proves to vary depending on the sector of the innovation. While eco-friendly innovations typically benefit from the environmental legislation and get accelerated by it, innovations related to, for example, medical devices, equipment or treatment, often face a considerably increased time-to-market because of complex regulatory requirements. We will elaborate on the role of regulation for the development of NMP innovations in the recommendations part of the report.

3.6. Specifics of New Production

As mentioned above, some of the aspects of New Production category significantly differ from New Products and Materials. In this sub-section, we elaborate on such aspects.

3.6.1. System-like innovation cycle

The production system's innovation cycle (see Figure 3-3) starts with the initial system design and synthesis according to the specified objectives and constraints. This step is then followed by modeling, analysis and simulation. Then the final design is realised, implemented and used in production. The production system undergoes re-design and reconfiguration, throughout its operation and as new requirements emerge and changes are required. The aim is to meet the requirement of constantly changing environment. Therefore, both soft (logical) and hard (physical) reconfiguration and flexibility are the enablers of change and can extend the utility, usability and life of manufacturing systems[58].

Production processes in general have a life cycle that in terms of duration is comparable to new products. However, given the decreasing duration of the life cycle of products, production processes need to incorporate a certain degree of flexibility and ability to adapt to the future product generations.

The study confirmed that ***the life cycle of a product is approximately in the same range of the life cycle of the production tools and technological processes*. *However, with the constantly decreasing market life of products, the installed processes and the equipment are now expected to produce the next product generation(s)***. The production systems have to be adaptable to two and sometimes three product generations, while they also must follow new requirements, for instance, regarding logistics and enviroment[59].

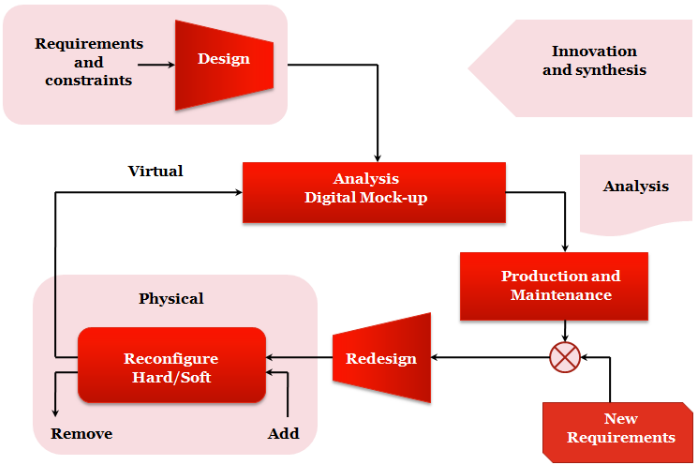


FIGURE 3-3: Innovation cycle for New Production[60]

3.6.2. Initial system design and synthesis according to the specified objectives and constraints and with worker involvement

From our findings we can conclude that before an advanced production system is designed, ***high-level decisions are made determining why and where this system should be used***. This may include the identification of which production processes are to be involved in the implementation and what level of technology is to be utilised. The next phase involves identifying what specific technology is to be purchased and

[58] ElMaraghy H.A. and Wiendahl H.P. (2009) Changeability – An introduction. In: ElMaraghy H.A. (ed.) *Changeable and Reconfigurable Manufacturing Systems*, Springer Series in Advanced Manufacturing

[59] See also ElMaraghy H.A. and Wiendahl H.P. (2009) Changeability – An introduction. In: ElMaraghy H.A. (ed.) *Changeable and Reconfigurable Manufacturing Systems*, Springer Series in Advanced Manufacturing

[60] adopted from ElMaraghy H.A. and Wiendahl H.P. (2009) Changeability – An introduction. In: ElMaraghy H.A. (ed.) *Changeable and Reconfigurable Manufacturing Systems*, Springer Series in Advanced Manufacturing

how it is to be implemented. When the organisation is determining why and where the new technology should be used, the use of a ***human-centred philosophy and worker involvement*** are shown to have a significant impact on the success of this step. We found that the presence of a technological champion has a far less significant impact on this success, and in several cases a technology champion could not be identified.

3.6.3. Engagement of experts in modelling, analysis and simulation

The next step in the innovation cycle of a new production system refers to modelling, analysis and simulation. A simulation model represents a surrogate for actually experimenting with a production system, which is often unfeasible or not cost-effective. Therefore, it is important for a simulation analyst to determine whether the simulation model is an accurate representation of the system being examined, i.e., whether the model is valid. It is also important for the model to be credible; otherwise, the results may never be used in the decision-making process, even if the model is valid. We found that successful innovations imply ***collecting information on the system layout and operating procedures based on conversations with the "expert" for each part of the system***. Also, successful innovations imply interacting with managers and users on a regular basis to make sure the innovation is being tested on the most useful aspects and to increase model credibility.

3.6.4. Focus on people during implementation

The final design and implementation phase covers the period between plan completion and initial operation of the new production system. It includes the physical installation of the production system and the development of supporting systems that enable the technology to function as a production process. The startup phase covers the period between the initial operation of the technology and operation of the technology in a production capacity[61]. The analysis suggests that during the implementation phase, where the physical installation and development of a new production system takes place, the ***human-centred philosophy, more capable workers, education and training for users, and use of pilot-level projects*** had a positive impact. This also holds when the implementation is moving towards operating in a production mode.

[61] Chung C.A. (1996) Human issues influencing the successful implementation of advanced manufacturing technology, Journal of Engineering and Technology Management 13 (1996), pp. 283-299

3.6.5. High degree of flexibility and reconfiguration in case of changing demands

Successful production process innovations allow for high degree of flexibility and reconfiguration in case of changing demands.

> **High degree of flexibility in the case of Ricoh**
> Ricoh replaced its conveyer belts with lines of robotic carts propelled by air pressure. This allowed Ricoh to easily adapt its production process to changing production volumes and model types. Also, this proved to save both energy and production space. Also, Ricoh has deployed a digital communication protocol that connects its sales force to the flexible cart line. Anywhere in the world, a Ricoh salesperson can forward orders digitally to Ricoh's plant in Gotemba, Japan, including customised features negotiated directly with the client. The information is then processed within the plant, instantly initiating the required manufacturing process with the production cell tailored to the specific manufacturing requirements, while allowing Ricoh's manufacturers to flexibly change the volume of production on a weekly basis and maintain production speed and efficiency even when faced with considerable fluctuations in demand.

3.6.6. Reliance on internal skills and competences

Companies that manage to successfully adapt advanced production technologies typically dislike being dependent on outsiders for expertise. They prefer to develop their own people, equipment, and systems, therefore they often put great effort into recruiting and training operating personnel. Additionally, they strive to build close working relationships throughout the company. Companies begin to realise that they need people who are more than experts and caretakers. They need architects and generalists, i.e., people who can design and implement totally new approaches. From our research it shows that for small companies the key internal stakeholders are the founders and young technology specialists, while for large companies the internal stakeholders are top managers, engineering staff, R&D managers, marketing personnel and operating personnel.

3.7. Comparison with Lot 1 findings

Most of the findings of one Lot are supported by the findings of the other, which strengthens the final arguments stemming from the synthesis of the results of the whole study.

As presented in Chapter 1, the current study consisted of two complementary parts, one focussing on the innovation trajectories of EU-funded research projects (*Lot 1*), and another one reconstructing the innovation cycles of commercially successful innovations barely supported by EU or other public funds (*Lot 2*). ***Although both Lots implied the analysis of the full innovation trajectories of the analysed cases, the differences in scoping have led to complementary approaches in terms of which parts of the innovation trajectories were dominating in the analysis of each Lot***. While the focus of Lot 1 leans more towards the *upstream* part of the innovation cycle, Lot 2 predominantly focuses on the *downstream* part of the innovation cycle (including successful market performance of the innovation). In their analyses, both Lots move along the innovation cycle towards each other, with a significant part of the cycle being the focus of both Lots and generating complementary findings.

Below we provide a brief comparison of findings of Lot 2 with Lot 1. Despite the abovementioned differences in the approaches of both Lots, ***most of the findings of one Lot are confirmed/supported by the findings of the other, which strengthens the final arguments stemming from the synthesis of the results of the whole study***. The key differences in findings can mainly be explained by the focus on different samples of both Lots, with one looking at (not always successful) consortia of academic and private players supported by public funds, and the other looking at mainly SMEs and other companies that successfully made it to the global market with a minimal involvement of public funds.

Research activity: emphasis on applied research

The findings of both Lots confirm that the majority of successful innovations are linked to R&D activities of more applied nature. Market-oriented exploitation is often an essential part already during the conceptualisation stage or, in fact, the trigger for developing a research project. At the same time, both Lots conclude that basic research projects are nevertheless fully capable of producing successful exploitation results by involving potential customers or end-users whose main task is refining the research outcome towards potential applications.

Lot 1 suggests that the involvement of industry in R&D consortia increases the success rate of market-oriented exploitation in general given their inherent orientation towards markets. Some cases of Lot 1, on the contrary, indicate that the potential for conflict of interest can also increase accordingly with higher industrial participation. In case of Lot 2, industrial involvement is central to the innovation trajectories, with SMEs and other companies being in the driver's seat of the R&D and commercialisation process.

Involvement of end users from the very beginning of the innovation cycle

Both Lots concluded that commercially successful projects involved (potential) end-users to safeguard the actual application of knowledge produced. While cases in Lot 2 did not signal any considerable disadvantages regarding the end-user involvement, Lot 1 results emphasise certain risks associated with it. Some cases from Lot 1 sample suffered from the fact that the involvement of end-users can limit the scope of thinking when it comes to the market-oriented exploitation.

This negative effect is suggested to be the strongest for those projects where the end-users focussed on one rather narrow industrial sector. Therefore, the positive effect of involving end-users is suggested to depend on the flexibility that is "left" with regard to application areas.

Exploring market opportunities as early as possible

Both Lots confirmed that successful innovations imply starting the exploration of market opportunities as early as possible, often even before a concept for a R&D project is developed. Additionally, successful innovations are almost always characterised by a constant feedback process between market analysis and research, and R&D project's concept and governance mechanisms need to allow for modifications based on that feedback throughout the process.

Designing market strategies: first to the market vs. entering the market at the right moment

Both Lots emphasise the vital role of timing when introducing the product to the market. Interestingly, while Lot 2 findings demonstrate the importance of "first to market" strategy, Lot 1 suggests that instead of being the first, it is rather being on the market at the 'right' time. These findings are related to the discussion on the so called first- and second-mover advantages.

First-mover advantage is the advantage gained by the initial significant 'occupant' of a market segment. Sometimes, first-movers are rewarded with large profit margins and a monopoly-like status; and sometimes the first-mover is not able to capitalise on its advantage, leaving the opportunity for other firms to compete effectively and efficiently versus their earlier entrants[62].

At the same time, first-mover firms often face high R&D and marketing costs necessary to educate the public about a new type of product. A second-mover firm can learn from the experiences of the first mover and may not face such high R&D costs if they are able create their own similar product using existing technology. A second-mover firm also does not need to educate the public about the new project because the first mover has already done so. As a result, the second-mover can use its resources to focus on making a superior product or out-marketing the first mover[63].

Both Lots confirm that the best option is to enter the market at the 'right' moment, which in some cases may mean being the first on the market (dominant scenario in Lot 2 sample), and in other cases means waiting a bit more and letting the first mover 'do the job'. ***Which***

[62] Grant, R. M. (2003) *Cases in Contemporary strategy analysis*. Blackwell publishing. ISBN 1-4051-1180-1.

[63] Epstein K. (2006) *Marketing made* easy. McGraw-Hill Companies, Incorporated, pp. 116–117. ISBN 978-1-59918-017-5.

strategy to choose depends on a broad array of factors including financial capabilities of the firm/consortium, access to the market, the level of readiness of the product and readiness of the team to compromise on the quality for the sake of timing, if needed, etc.

Team's flexibility and openness towards new ways of doing things

Both Lots suggested that the ability and willingness to act flexibly (as either a group of organisations or an individual one) not only supports success in commercially exploiting research outcomes but in some cases facilitates the multiplication of applications and thus, potential customers, and reduces economic risks by diversification.

Resistance from the customers' side

Lot 1 signalled that some industries are not able or willing to purchase and integrate innovations at the same pace that research and innovation projects could provide them. In those cases, organisations tend to commercially exploit *parts* of what they developed, marketing their innovation "bit by bit", sometimes even "hiding" an innovative characteristic or feature to the customer in order to avoid rejection due to reluctance.

Interestingly, Lot 2 cases facing similar challenges demonstrated their ability to transform this 'disadvantage' of being too new/radical into a key advantage by means of using effective marketing strategies (see, for example, the case of APADENT and APAGARD Nanohydroxyapatite Toothpaste which the world had never seen before and which was quite expensive due to the high R&D costs for the radical technology; it was nevertheless successfully marketed as "The most expensive toothpaste in the world" because of its unique properties).

Customer valley of death: first customer does not yet mean success

Both Lots emphasised the difficulties of attracting avantgarde customers or early adopters on the market, i.e., the customers that signal to the market that a technology is safe, well performing, and can be integrated into existing production processes. The observations of Lot 1 indicate that innovation managers tend to have a perception that it is all about getting the first customer, and once it is there, the market success is more or less guaranteed. The analysis of Lot 2 (focussing on the downstream parts of the innovation cycle), however, clearly demonstrates that getting the first customer is just the first step into the 'customer' valley of death, with each following customer segment (closer to the mainstream market) requiring considerable adjustments in the product itself and in the marketing strategies, otherwise the first customer is likely to become the last one too[64].

3.8. Key conclusions from the study

The current chapter presented detailed study findings. Below we provide a concise overview of the key conclusions derived from the study.

- NMP is fast becoming an important business area for companies in a diverse range of industries. It is expected to have a major influence on virtually all sectors where materials play a role, such as aerospace and defence, electronics, energy, life sciences and healthcare, textiles, environment, water, food, construction, consumer goods, household care, security, automotive, chemicals and coatings.
- NMP innovations imply complex, multidisciplinary and potentially disruptive nature of the innovation cycle. NMP market is not a single market but a series of enabling technologies that provide groundbreaking solutions to critical challenges in various industries.
- Products based on NMP and enabling technologies in general often draw not simply upon multiple innovations, but upon multiple innovations from various disciplines.
- All NMP innovations can be split into three main categories: New Products, New Materials and New Production. Our empirical analysis confirmed the *significant differences* between the progression of innovations within these three categories.
- New Products and New Materials categories proved to have somewhat comparable innovation trajectories. A key difference refers to the fact that the innovation trajectory of New Materials typically feeds into the innovation trajectory of New Products. Additionally, since materials are embedded in products, any risks that exist in the product market are amplified in the materials market.
- In case of New Production, one has to deal with different types of activities, decisions and challenges when compared with New Products and New Materials, and these differences should be taken into consideration when developing effective policy measures.
- Rather than being a chain of subsequent steps, the NMP innovation trajectory represents a continuous process with close interrelations between various parallel activities. While from a strategic

[64] For more information on this point, see Moore G.A. (2001) *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers*, HarperCollins Publishers

perspective, the objective of these activities remains the same all the time, the way these activities are performed operationally evolves over time.

- An activity playing a key role in the innovation trajectory refers to the interaction with users, designers and engineers, which, in case of successful innovations, happens throughout the whole innovation process.
- Successful NMP innovations result from a combination of both technology push and market pull, i.e., there needs to be a clear demand for the innovation, but at the same time, the technology should be at the level that is advanced enough to satisfy that demand and to create new markets.
- Companies typically try to introduce the NMP innovations to the market as soon as possible. However, if the innovation falls under a highly regulated sector (e.g., healthcare sector, such as medical devices, equipment or treatment), time-to-market significantly increases because of regulatory requirements.
- The development of NMP innovations from the sample was often mainly supported by private funds coming from own savings, company's own funds and business angels in the beginning, and venture capital investors at later stages. However, private funds were often triggered by the use of public funds, which corresponds to the concept of 'smart' public funding.
- The public funds used by the analysed cases primarily included national grants for joint research projects between university and industry by national ministries, tax deduction schemes for R&D activities, loans with governmental guarantees, and other measures stimulating interaction and exchange between the universities and SMEs. Some of the analysed cases benefited from public support for the activities closer to the market which can partially explain the success of the exploitation of their research results.
- The successful NMP innovations are highly flexible, i.e., they are designed in such way that it is easy to respond to the rapidly changing environment and to incorporate user feedback.
- Other key factors determining the success of the innovation refer to so called human factors or people standing behind the innovation, which includes charismatic leaders and intrinsically highly motivated teams.
- When comparing EU and non-EU cases, hardly any differences were detected between the successful cases from different world regions with regard to both micro- and macro-level factors. There is a set of

common trends that can be observed among the majority of the global innovation showcases despite their geographical location.

- At the micro-level, those trends among others include highly motivated teams and charismatic leaders, active early engagement with end-users and good access to private funds.
- At the macro-level, the role of regulation proves to vary depending on the sector of the innovation. While eco-friendly innovations typically benefit from the environmental legislation and get accelerated by it, innovations related to, for example, medical devices, equipment or treatment, often face a considerably increased time-to-market because of complex regulatory requirements. We will elaborate on the role of regulation for the development of NMP innovations in the recommendations part of the report.

The key conclusions for each of the innovation activities can be summarised as follows.

Activity 1: Research

- Key research-related challenges refer to availability of knowledge within the company/team; the need to tackle technical problems nobody ever tackled before; and the need to balance between quality and price due to budget limitations.
- In the analysed sample, research that has led to commercially successful NMP products was more often privately, rather than publicly funded. However, as mentioned above, private funds were often triggered by the use of public funds, which corresponds to the concept of 'smart' public funding. Some of the analysed cases benefited from public support for the activities closer to the market which can partially explain the success of the exploitation of their research results.
- Public funds also proved to be vital for basic research at universities (which forms the basis for NMP innovations), as well as in cases when innovation is commercialised by means of a university spin-off.

Activity 2: Interaction with users, designers and engineers

- Successful NMP innovations demonstrate an active involvement of a broad community of users, designers and engineers from the very beginning of their innovation trajectory.
- This involvement may take different forms such as: online collaboration platforms with a broader community; direct contacts

with users, designers and engineers at company’s premises, conferences, fairs and/or other events; interaction with a broader community by means of web blogs and emails; engagement in open source approach etc. The form chosen depends on the development stage of the innovation, type of innovation, and resources (financial and time) available for such interactions.

- Companies actively use their first buyers to collect valuable feedback that would be later translated into significant improvements of the innovation.

Activity 3: Exploring market opportunities

- Companies explore the competition by means of either relatively simple Internet search or by following a more rigorous approach including conversations with potential competitors.
- Some companies make competition analysis their regular activity rather than a one-time exercise.
- Key reasons for not performing the competition analysis refer to perceived strong knowledge of the market and lack of competition, as well as limited financial resources.

Activity 4: Protecting and managing Intellectual Property Rights

- Different scenarios are possible regarding the creation of IP for NMP innovations, and there is no one best way to deal with IP. It depends, among others, on whether IP already exists or needs to be created, the risk of substitution, as well as the size and financial capacity of a company.
- Filing of a patent for a NMP innovation often involves a team of scientists representing many scientific disciplines collaborating on a technology comprising multiple components, each of which might require multiple IP Rights.
- Any sensitive information on the innovation is never disclosed without a signed confidentiality agreement.

Activity 5: Prototyping and industrial demonstration

- A prototype is a necessary prerequisite for a successful innovation. To understand a real technological concept, the buyer often needs to see the product that has the technology imbedded in it. Additionally, prototypes allow to understand, identify, and prevent failures before the manufacturing stage is reached.

- The prototype stage involves proprietary control via patent or other IP protection mechanisms.
- The prototype stage involves close contacts with customers and collaboration partners.
- Companies prefer to carry out prototyping activities in house.

Activity 6: Product trials and sales

- Successful NMP innovations are clearly named and framed. Their positioning specifies the relevant R&D aspects and potential applications, key product features and direct customer benefits. In many cases, this information is available online.
- To achieve a competitive advantage, companies may claim that their product is of unique nature and that no comparable options are currently available on the market. To emphasise the uniqueness of the product, some companies chose high price strategy. In other cases, the product had to be made affordable to penetrate the market.
- When developing marketing strategies for NMP innovations, there is a need to embrace a broader concept of innovation, including its non-technological aspects such as design, creativity, service, communication, process and business model innovation, i.e. social innovation. Social innovation goes hand in hand with NMP technological innovation, and proves to be decisive for successful market entry and commercial growth.
- In case of highly technical innovations, the product often may need to be brought to customers and demonstrated 'in real' to achieve sales.
- The dissemination channels, pricing and marketing strategy differs depending on the innovation's category and its technical complexity. While highly complex NMP products are typically sold by means of physical presentations and demonstrations at client's premises or during trade shows, mainstream-market oriented products are promoted by means of TV commercials and smart merchandising.

Activity 7: Industrialisation

- Key success factors here include careful selection of an external manufacturing company which could provide detailed feedback; working with small-size partners allows for making decisions quickly; and working with used equipment through Internet auctions.

Activity 8: Managing innovation

- Successful NMP innovations imply the involvement of multidisciplinary teams. The NMP product design engineers work closely with process, equipment, manufacturing, assembly, and facilities engineers. Small companies often team up with established companies to help them validate products, provide a channel for marketing and selling products, and provide expertise in manufacturing.

- Managers of successful NMP innovations do not think in terms of silos. They grant a considerable amount of freedom to the team to conduct research and develop the innovation.

- Managers of successful innovations are open for ideas from outside (open innovation concept).

- Successful NMP innovations imply the engagement of diverse stakeholder groups (e.g., actors of the market, actors of the value chain, partners in research projects, public actors, etc.).

4. Success markers

In the course of the study, we focused on the traceability of the innovation cycle from the introduction of innovations to the market back to their technical source or origin, including the key steps, diffusion time and patterns. Such analysis allowed us to extract the factors explaining or easing the implementation and success of NMP innovations at each of the abovementioned phases. We also identified the key obstacles that have been encountered during the diffusion and implementation phase after completion of work at research/technology level, and how those have been overcome. Finally, we analysed the channels of dissemination of technical information that have proved effective or less effective. All these analyses allowed us to develop a set of straightforward ***success markers*** or factors common among commercially successful NMP innovations. Success markers aim to show what proves to be vital in determining whether an innovation will be successful on the market or not, and consequently ***indicate areas that require special attention from the policy makers' side***.

In the current chapter, we present a detailed overview of the identified success markers, and distinguish between the applicable success markers for New Products and Materials, *and* New Production. We tailor the success markers to the context of consortia of public and private entities. Additionally, we develop a set of success markers applicable specifically to high-tech SMEs. In this chapter, we aim to familiarise the reader with different sets of success markers, and in the next chapter, we will elaborate on the policy implications of this ***central output of the study***.

4.1. Success markers for New Products and Materials

As mentioned in the previous chapter, New Products and New Materials categories proved to have somewhat comparable innovation trajectories. When developing success markers, it allows to combine them in one broader category of NMP innovations.

The proposed success markers build on the notion of continuous and evolutionary nature of innovation activities, and can be clustered into three main groups corresponding to TRL 2-4, TRL 5-8 and TRL 9 respectively (in line with the recommendation in the Final Report of the High Level Expert Group on Key Enabling Technologies[65]). Table 4-1 presents the success markers in chronological sequence split into three sets as explained above.

[65] http://ec.europa.eu/enterprise/sectors/ict/files/kets/hlg_report_final_en.pdf

TABLE 4-1: Success markers for NMP Products and Materials (1 – totally inapplicable to this project; 3 – partially applicable to this project; 5 – fully applicable to this project)

Nr	Activity	Success marker	1	2	3	4	5
Phase 1 (TRL 2-4)							
1.1	Research (1)	Research from its early stage is closely linked to feedback incorporation from end-users and exploration of market opportunities.					
1.2	Research (1)	The project team (consortium) uses research facilities of a participating university/research center which allows for access to unique and expensive equipment.					
1.3	Research (1)	Both technology push and market pool are present simultaneously, i.e., there is a clear demand/market for the innovation, but at the same time, the technology is at the level that is advanced enough to satisfy the existing demand and to create new markets.					
1.4	Innovation management (8)	The research team consists of highly motivated and highly skilled people with talent and passion for this specific research.					
1.5	Innovation management (8)	When research is conducted by a company, CEO shows commitment and support to the project (including allocation of company's funds). When research is conducted by a university/research institute, the commitment is shown by the head of laboratory/department.					
1.6	Innovation management (8)	Much freedom is granted to the team to conduct research and develop the innovation.					
1.7	Interaction with users, designers and engineers (2)	An active involvement of a broad community of users, designers and engineers begins as direct contacts at company's premises, conferences, fairs and/or other events.					
1.8	Exploring market opportunities (3)	There is a good understanding not only of the market for that particular innovation, but also of the agendas and markets of its potential buyers.					
1.9	Exploring market opportunities (3)	There is a good knowledge of the relevant regulatory and standardisation aspects, and the identified market opportunities are assessed in light of the latest developments.					
1.10	Protecting and managing IPR (4)	Through non-disclosure, consortium members are obliged to keep sensitive information confidential and ensure any disclosure of such information is done in confidence and with prior permission[66].					
1.11	Protecting and managing IPR (4)	The IP rules take into account the mission and legitimate interests of both public research institutes and participating industrial partners.					

[66] See also http://www.innovationtoolbox.com.au/manage-intellectual-property/5-protecting-ip

1.12	Protecting and managing IPR (4)	Internal procedures are established to review organisational publications including journal, presentations, brochures, posters, correspondence, press releases and other forms of public disclosures and this material is reviewed each time before release.					
1.13	Protecting and managing IPR (4)	The maintenance of systematic records of all developmental or experimental work is performed (which is beneficial for IP protection purposes, either in enforcing infringement of others or defending infringement claim by others). Good record-keeping includes using bound notebooks, with pages consecutively numbered, dated, signed and witnessed, chronological, thorough and written using permanent ink.					
1.14	Protecting and managing IPR (4)	Once the decision has been made to proceed with IP protection, an IP lawyer or attorney is professionally engaged to assist with the formal protection and advisory work.					
1.15	Prototyping and industrial demonstration (5)	First basic prototype is developed. The prototype still has a research status, but it is moving from purely theoretical calculations toward a proof in reality as tests are being verified and the results can be seen in a laboratory.					
1.16	Protecting and managing IPR (4)	By the beginning of the prototyping activity, proprietary control via patent or other IP protection mechanisms is established.					
1.17	Innovation management (8)	The team is open for ideas from outside (open innovation concept).					
Phase 2 (TRL 5-8)							
2.1	Research (1)	Success markers helping to attract funding include the charismatic nature of the entrepreneur (e.g., the ability to convince and negotiate), technically well-prepared presentations, rigorous market research, and well thought trough marketing and pricing strategies.					
2.2	Innovation management (8)	Consortium managers serve as a catalyst and coach, keeping everyone focused on the end goal and making sure the team is doing whatever it takes to overcome the powers/inertia that hold back the innovation.					
2.3	Interaction with users, designers and engineers (2)	First (potential) buyers are used to collect valuable feedback that will be later translated into significant improvements of the product.					
2.4	Exploring market opportunities (3)	Segmentation of competitors is performed before entering the market.					

2.5	Exploring market opportunities (3)	Market penetration strategies are assessed in light of the latest regulatory and standardisation developments with the aim to minimise the negative effects of the relevant regulatory barriers and to maximise the benefits of the relevant aspects supported by the regulation and standards.					
2.6	Protecting and managing IPR (4)	Clear agreements are made with suppliers and manufacturers (e.g., restricting the agreement to a certain technology field; restricting the agreement to a certain application or market field; restricting the agreement in time).					
2.7	Product trials and sales (6)	Active contacts are made with potential customers and collaboration partners. First product trials are performed by customers.					
2.8	Protecting and managing IPR (4)	An analysis of intellectual asset portfolios is performed, and programs for their monitoring and enforcement are developed and implemented.					
2.9	Protecting and managing IPR (4)	A review of the opportunities for investing in acquisition or creation of different forms of IP is performed. This stage also involves the application of corporate investment policies and practices to IP management investments for creating a platform for other investment priorities.					
2.10	Prototyping and industrial demonstration (5)	A broader user and engineer community is involved in advancing the prototype.					
2.11	Prototyping and industrial demonstration (5)	An industrial demonstrator allows to understand, identify, and prevent failures before the manufacturing stage is reached. Possible failure modes in different environments are thoroughly tested to ensure that failure model predictions are verified.					
2.12	Product trials and sales (6)	The innovation is clearly named (i.e., it has a catchy and easy-to-understand name) and framed (i.e., it specifies who it is for and what it is for).					
2.13	Product trials and sales (6)	The innovation offers its early adopters a clear comparative business advantage, e.g., lower product costs, faster time-to-market, more complete customer service.					
2.14	Product trials and sales (6)	A specific niche market is targeted where the innovation can force its competitors out of the market niche, and then use it as a base for broader operations.					
Phase 3 (TRL 9)							
3.1	Research (1)	The end-product is continuously updated based on user feedback and latest research results.					
3.2	Interaction with users, designers and engineers (2)	Interaction with users grows into online collaboration platforms with a broader community; web blogs and emails; engagement in open source approach.					

3.3	Industrialisation (7)	Careful selection of an external manufacturing company is made which could provide detailed feedback on product design. Working with used equipment through Internet auctions to reduce costs. Working with small-size partners allows for making decisions quickly.					
3.4	Protecting and managing IPR (4)	Information technology tools are used to capture and manage critical intellectual asset portfolio information in order to sustain IP profits and protect existing IP investments.					
3.5	Prototyping and industrial demonstration (5)	An industrial demonstrator takes into account all stages of manufacturing and includes all aspects of packaging to achieve a successful end product.					
3.6	Product trials and sales (6)	To penetrate the initial target segment, direct sales are (often) used. Once the segment is aware of the innovation's presence and leadership, the transition is made to the most efficient channel for that particular case.					
3.7	Exploring market opportunities (3)	Market opportunities are pursued aggressively. However, if the target market is too large to be approached directly, then less aggressive measures are also mobilised (e.g., participation in scientific events, publications, brochures, newsletters and fairs).					
3.8	Exploring market opportunities (3)	The results of the market strategy are carefully monitored, and adjustments introduced if needed. Market strategy is periodically reassessed also in light of the latest regulatory and standardisation developments.					
3.9	Product trials and sales (6)	The innovation's transition from an early market to a mainstream market implies a complete revision of the market strategy (positioning, segments, pricing etc.).					
3.10	Product trials and sales (6)	When targeting a mainstream market, the innovation's positioning demonstrates how this innovation is different from the competitors.					
3.11	Product trials and sales (6)	The price of the whole product is consistent with the target customer's budget.					
3.12	Innovation management (8)	Market relations are built with all the key members of a high-tech marketplace (i.e., customers, press, and analysts, hardware and software partners, distributors, dealers, VARs [value-added-resellers], system integrators, user groups, vertically oriented industry organisations, universities, standards bodies, and international partners).					

4.2. Success markers for New Production

As mentioned before, larger differences can be observed when comparing New Products and New Materials with the progression of New Production innovations. The latter category includes the new ways of organising manufacturing and new business models. An innovation cycle of a production system is something completely different than an innovation cycle of a material or a product. It typically starts with the initial system design and synthesis according to the specified objectives and constraints. This step is then followed by modelling, analysis and simulation. Then the final design is realised, implemented and used in production. The production system undergoes re-design and reconfiguration, throughout its operation and as new requirements emerge and changes are required. Consequently, in case of New Production, one has to deal with different types of activities, decisions and challenges when compared with New Products and New Materials, and ***these differences should be taken into consideration when developing effective criteria for the initial FP7/H2020 project assessment, as well as monitoring and final evaluation***. Therefore, based on the study findings, for this category of NMP innovations, we have developed a different set of success markers as presented in Table 4-2.

TABLE 4-2: Success markers for New Production

Nr	Success marker
1 Initial system design and synthesis according to the specified objectives and constraints	
1.1	The support of the top management is obtained soon after the conceptual idea has been articulated.
1.2	The system design implies collaborations across organisational boundaries and top managers being involved.
1.3	A buffer is imbedded in the planning to deal with possible unforeseen challenges.
1.4	There is the presence of technological skill and know-how within the company, as well as vision and determination within the top management of the company on the benefits of the innovation.
1.5	Designers have enough freedom to select among different physical implementation alternatives, separating the system's objectives from the means of achievement.
1.6	Low-level activities and decisions are linked to high-level goals and requirements by assembling multi-competence teams.
1.7	There is a good understanding of interrelationships among the different elements of a system design, for instance by studying these interrelationships in detail and involving users in an early stage of the design.
1.8	In small companies, communication on the innovation takes place rather informally within tight knit teams. In large companies or in situations with large user communities, communication happens through speeches, presentations, e-learnings, video tutorials and so on.
1.9	Development roadmaps are in place, and the objectives are well articulated by the leaders of the innovation and understood by the designers involved. However, trial and error can also play an important role.

2 Modelling, analysis and simulation	
2.1	User testing, pilot testing, running simulations in experimental set ups, and prototyping the design are performed.
2.2	Users and operating personnel are involved to improve the quality of test results and the adoption of the process.
2.2	Additional investments are made in time, tools and knowledge.
2.3	Information is collected on the system layout and operating procedures based on conversations with the experts for each part of the system.
2.4	Interaction with managers happens on a regular basis to make sure that the correct problem is being solved and to increase model credibility.
3 Final design and implementation	
3.1	Training is offered to the users on how to enjoy the benefits of the new process. Users learn and develop competence in using the innovation, use those competencies in the manufacturing process, and continue using the innovation willingly.
3.2	The innovation offers a holistic approach and allows for full integration with existing processes.
3.3	Companies align their new production systems with customer and supplier relationships.
4 Redesign and reconfiguration	
4.1	Continuous or repeated periodical redesign and reconfiguration efforts, both on physical and on logical aspects take place.
4.2	User feedback is constantly collected and the innovative technology is customised to the user needs, redesigning the process along newly formulated requirements.
4.3	The innovation allows for high degree of flexibility and reconfiguration in case of changing demands.

4.3. Success markers in the context of high-tech SMEs

The previous sets of success markers were relevant for consortia of public and private entities. Table 4-3 provides an overview of success markers developed specifically for high-tech SMEs.

TABLE 4-3: Success markers for high-tech SMEs (1 – totally inapplicable to this project; 3 – partially applicable to this project; 5 – fully applicable to this project)

Nr	*Activity*	*Success marker*	*1*	*2*	*3*	*4*	*5*
Phase 1 (TRL 2-4)							
1.1	Research (1)	Research from its early stage is closely linked to feedback incorporation from end-users and exploration of market opportunities.					
1.2	Research (1)	The team uses research facilities of a university/research center which allows for access to unique and expensive equipment and social networks of academic researchers.					
1.3	Research (1)	Both technology push and market pool are present simultaneously, i.e., there is a clear demand/market for the innovation, but at the same time, the technology is at the level that is advanced enough to satisfy the existing demand and to create new markets.					

Nr	Activity	Success marker	1	2	3	4	5
1.4	Innovation management (8)	The research team consists of highly motivated and highly skilled people with talent and passion for this specific research.					
1.5	Innovation management (8)	If research is conducted by a company, CEO shows commitment and support to the project (including allocation of company's funds).					
1.6	Innovation management (8)	Much freedom is granted to the team to conduct research and develop the innovation.					
1.7	Interaction with users, designers and engineers (2)	An active involvement of a broad community of users, designers and engineers begins as direct contacts at company's premises, conferences, fairs and/or other events.					
1.8	Exploring market opportunities (3)	There is a good understanding not only of the market for that particular innovation, but also of the agendas and markets of its potential buyers.					
1.9	Exploring market opportunities (3)	There is a good knowledge of the relevant regulatory and standardisation aspects, and the identified market opportunities are assessed in light of the latest developments.					
1.10	Protecting and managing IPR (4)	Through non-disclosure, employees are obliged to keep sensitive information confidential and ensure any disclosure of such information is done in confidence and with prior permission[67].					
1.11	Protecting and managing IPR (4)	A clear IP ownership clause is incorporated in employment contracts such that ownership of all IP generated during employment shall be the property of the employing business.					
1.12	Protecting and managing IPR (4)	Internal procedures are established to review organisational publications including journal, presentations, brochures, posters, correspondence, press releases and other forms of public disclosures and this material is reviewed each time before release.					
1.13	Protecting and managing IPR (4)	The maintenance of systematic records of all developmental or experimental work is performed (which is beneficial for IP protection purposes, either in enforcing infringement of others or defending infringement claim by others). Good record-keeping includes using bound notebooks, with pages consecutively numbered, dated, signed and witnessed, chronological, thorough and written using permanent ink.					
1.14	Protecting and managing IPR (4)	Once the decision has been made to proceed with IP protection, an IP lawyer or attorney is professionally engaged to assist with the formal protection and advisory work.					

[67] See also http://www.innovationtoolbox.com.au/manage-intellectual-property/5-protecting-ip

Nr	Activity	Success marker	1	2	3	4	5
1.15	Prototyping and industrial demonstration (5)	First basic prototype is developed. The prototype still has a research status, but it is moving from purely theoretical calculations toward a proof in reality as tests are being verified and the results can be seen in a laboratory.					
1.16	Protecting and managing IPR (4)	By the beginning of the prototyping activity, proprietary control via patent or other IP protection mechanisms is established.					
1.17	Innovation management (8)	The team is open for ideas from outside (open innovation concept).					
Phase 2 (TRL 5-8)							
2.1	Research (1)	Success markers helping to attract funding include the charismatic nature of the entrepreneur (e.g., the ability to convince and negotiate), technically well-prepared presentations, rigorous market research, and well thought trough marketing and pricing strategies.					
2.2	Innovation management (8)	Managers serve as a catalyst and coach, keeping everyone focused on the end goal and making sure the team is doing whatever it takes to overcome the powers/inertia that hold back the innovation.					
2.3	Interaction with users, designers and engineers (2)	First (potential) buyers are used to collect valuable feedback that will be later translated into significant improvements of the product.					
2.4	Exploring market opportunities (3)	Segmentation of competitors is performed before entering the market.					
2.5	Exploring market opportunities (3)	Market penetration strategies are assessed in light of the latest regulatory and standardisation developments with the aim to minimise the negative effects of the relevant regulatory barriers and to maximise the benefits of the relevant aspects supported by the regulation and standards.					
2.6	Protecting and managing IPR (4)	Clear agreements are made with suppliers and manufacturers (e.g., restricting the agreement to a certain technology field; restricting the agreement to a certain application or market field; restricting the agreement in time).					
2.7	Product trials and sales (6)	Active contacts are made with potential customers and collaboration partners. First product trials are performed by customers.					
2.8	Protecting and managing IPR (4)	An analysis of intellectual asset portfolios is performed, and programs for their monitoring and enforcement are developed and implemented.					

Nr	Activity	Success marker	1	2	3	4	5
2.9	Protecting and managing IPR (4)	A review of the opportunities for investing in acquisition or creation of different forms of IP is performed. This stage also involves the application of corporate investment policies and practices to IP management investments for creating a platform for other investment priorities.					
2.10	Prototyping and industrial demonstration (5)	A broader user and engineer community is involved in advancing the prototype.					
2.11	Prototyping and industrial demonstration (5)	An industrial demonstrator allows to understand, identify, and prevent failures before the manufacturing stage is reached. Possible failure modes in different environments are thoroughly tested to ensure that failure model predictions are verified.					
2.12	Product trials and sales (6)	The innovation is clearly named (i.e., it has a catchy and easy-to-understand name) and framed (i.e., it specifies who it is for and what it is for).					
2.13	Product trials and sales (6)	The innovation offers its early adopters a clear comparative business advantage, e.g., lower product costs, faster time-to-market, more complete customer service.					
2.14	Product trials and sales (6)	A specific niche market is targeted where the innovation can force its competitors out of the market niche, and then use it as a base for broader operations.					
Phase 3 (TRL 9)							
3.1	Research (1)	The end-product is continuously updated based on user feedback and latest research results.					
3.2	Interaction with users, designers and engineers (2)	Interaction with users grows into online collaboration platforms with a broader community; web blogs and emails; engagement in open source approach.					
3.3	Industrialisation (7)	Careful selection of an external manufacturing company is made which could provide detailed feedback on product design. Working with used equipment through Internet auctions to reduce costs. Working with small-size partners allows for making decisions quickly.					
3.4	Protecting and managing IPR (4)	Information technology tools are used to capture and manage critical intellectual asset portfolio information in order to sustain IP profits and protect existing IP investments.					
3.5	Prototyping and industrial demonstration (5)	An industrial demonstrator takes into account all stages of manufacturing and includes all aspects of packaging to achieve a successful end product.					

Nr	Activity	Success marker	1	2	3	4	5
3.6	Product trials and sales (6)	To penetrate the initial target segment, direct sales are (often) used. Once the segment is aware of the innovation's presence and leadership, the transition is made to the most efficient channel for that particular case.					
3.7	Exploring market opportunities (3)	Market opportunities are pursued aggressively. However, if the target market is too large to be approached directly, then less aggressive measures are also mobilised (e.g., participation in scientific events, publications, brochures, newsletters and fairs).					
3.8	Exploring market opportunities (3)	The results of the market strategy are carefully monitored, and adjustments introduced if needed. Market strategy is periodically reassessed also in light of the latest regulatory and standardisation developments.					
3.9	Product trials and sales (6)	The innovation's transition from an early market to a mainstream market implies a complete revision of the market strategy (positioning, segments, pricing etc.).					
3.10	Product trials and sales (6)	When targeting a mainstream market, the innovation's positioning demonstrates how this innovation is different from the competitors.					
3.11	Product trials and sales (6)	The price of the whole product is consistent with the target customer's budget.					
3.12	Innovation management (8)	Market relations are built with all the key members of a high-tech marketplace (i.e., customers, press, and analysts, hardware and software partners, distributors, dealers, VARs [value-added-resellers], system integrators, user groups, vertically oriented industry organisations, universities, standards bodies, and international partners).					

5. Recommendations

The current chapter aims to present detailed policy recommendations based on the findings and conclusions of the study. The recommendations aim to shed light on the question of ***how to best fund research projects in the NMP area to improve the results in terms of exploitation***. Specifically, the suggestions presented here aim to show how to increase the innovation output in the Framework Programme project cycle and in the future Horizon 2020 Programme, and in particular, how to foster innovation at all the stages of the project cycle; expand the exploitation side of projects (closer to market take up); *and* improve the entrepreneurial strategies and capacities of partners in Framework Programme projects. We also elaborate on the link between the proposed measures and other relevant existing or future policy instruments.

We begin with a set of specific recommendations on the process improvement for FP7- and future H2020-related actions. The latter refer to drafting calls for proposals, setting expectations, developing evaluation criteria, assessing, selecting and monitoring projects. The recommendations thus aim at helping the Commission to increase the effectiveness of FP7- and future H2020-funded NMP projects from a ***project management*** perspective.

We then develop a series of recommendations that focus on a broader view on stimulating NMP innovations, and specifically measures and tools to support both ***technology push*** and ***market pull***. As presented earlier, both need to be present simultaneously for NMP innovations to become commercially successful, i.e., there needs to be a clear demand/market for the innovation, but at the same time, the technology should be at the level that is capable to satisfy the existing demand and to create new markets. Both technology push and market pull can be influenced by public policies.

Consequently, the recommendations presented in this chapter can be grouped into three main categories:

(1) Recommendations on the process improvement for FP7- and future H2020-related actions from a project management perspective;

(2) Recommendations on supporting technology push of NMP innovations;

(3) Recommendations on supporting market pull of NMP innovations.

The recommendations presented in this report have been developed from the perspective that policies should be used for attracting private funds rather than substituting those, i.e., the concept of 'smart' public funding presented in the previous chapter of the report. A set of proposed adjustments aims to achieve better targeted policy measures allowing to maximise policy impact.

Finally, the presented recommendations are primarily addressed towards European policy makers. However, in order to achieve a synergetic effect, there is a clear need for corresponding adjustments in national and regional instruments. That would allow for strengthening Europe's ability to translate (publicly funded) research results into commercial successes at all levels.

5.1. Recommendations on the process improvement for FP7- and future H2020-related actions from a project management perspective

The recommendations presented in this section focus on the following aspects:

- Introducing evidence-based systematic framework for NMP project selection, monitoring and evaluation;
- Taking into account the continuous and evolutionary nature of innovation activities;
- Developing a standardised point system; *and*
- Communicating the new framework to project partners;

5.1.1. Introducing evidence-based systematic framework for NMP project selection, monitoring and evaluation

The quality of the decision making with regard to the funding of NMP projects can be improved by advancing the *quality* and *relevance* of the information base such decisions rely on. The latter, in turn, can be achieved by means of introducing an evidence-based systematic framework for project selection, monitoring and evaluation, i.e., a framework allowing for an objective well-informed analysis of the project's potential, progress and results.

Effective decision making with regard to the funding of NMP projects requires evidence-based systematic framework for project selection, monitoring and evaluation.

Project selection typically occurs in the context of high uncertainty and is based on a highly limited 'hardcore' evidence of possible commercial potential of the proposal in question. Cross-referencing the elements of the proposal with a set of evidence-based objective predictors of commercial success is likely to reduce the uncertainty level for the evaluators and thereby support a better informed decision making.

Monitoring implies observing whether intended project results are delivered (result indicators) and whether implementation is on track (process indicators). For the latter, monitoring also enables to determine whether the available resources are being well used, and whether the capacity is sufficient and appropriate.

FP projects are implemented in the context of complex consortia with a clear division of roles and responsibilities. Consortium participants (universities and research institutes, other public bodies, small and large companies etc.) all have different requirements with regard to the results that need to be achieved. It is therefore crucial to aggregate information across all participants in order to be able to judge on the overall progress of the project, and that requires applying common (composite) indicators. Tracking the values of result indicators, in turn, allows for a judgement on whether or not the project moves in the desired direction. If not, this can prompt reflection on the appropriateness and effectiveness of interventions and on the appropriateness of the result indicators chosen[68].

Evaluation, in turn, is the comparison of the actual results against the agreed plans at a certain point of time (in contrast to monitoring which is a continuous process). Evaluation results allow to conclude whether the objectives of the project are being achieved, what the strongest areas are, and which areas require special attention. In line with the CSF Regulation (Annex IV)[69], the evaluation indicators should meet the following quality requirements:

- capturing the essence of a result according to a reasonable argument about which features they can and cannot represent;
- having a clear and accepted normative interpretation (i.e. there must be agreement that a movement in a particular direction is a favourable or an unfavourable result);
- be robust and reliable;
- be timely collected.

[68] See also the Guidance Document (2011) on "Concepts and Recommendations for "MONITORING AND EVALUATION OF EUROPEAN COHESION POLICY - EUROPEAN REGIONAL DEVELOPMENT FUND AND COHESION FUND: The Programming Period 2014 - 2020", available at http://ec.europa.eu/regional_policy/sources/docoffic/2014/working/wd_2014_en.pdf

[69] Cited by the Guidance Document (2011) on "Concepts and Recommendations for "MONITORING AND EVALUATION OF EUROPEAN COHESION POLICY - EUROPEAN REGIONAL DEVELOPMENT FUND AND COHESION FUND: The Programming Period 2014 - 2020", available at http://ec.europa.eu/regional_policy/sources/docoffic/2014/working/wd_2014_en.pdf

Furthermore, similarly to monitoring and due to the complex consortia structure, for the final evaluation judgement, there is a need for applying common (composite) indicators.

After informed selection, projects therefore need to be continuously monitored, as well as evaluated at several points in time since orienting assessments solely toward outcomes is likely to produce a deficit of information that is needed for strategic short- and medium-term decision making. Furthermore, rather than being separate unrelated exercises, ***project selection, monitoring and evaluation need to be closely interlinked and serve one overarching objective of understanding the chances of commercial success of the funded NMP innovation and obtaining knowledge on how to increase those chances***.

The approaches towards project selection, monitoring and evaluation need to be closely interlinked and serve one overarching objective of understanding the chances of commercial success of the funded NMP innovation and obtaining knowledge on how to increase those chances.

Below we elaborate on the specific elements of the proposed evidence-based systematic framework that aims to serve the abovementioned objective.

5.1.2. Taking into account the continuous and evolutionary nature of innovation activities

This study has shown that NMP innovation trajectory model represents a continuous process with close interrelations between various activities. Furthermore, while from a strategic perspective, the essence/objective of these activities remains the same all the time, the way these activities are performed operationally evolves over time.

The framework for project selection, monitoring and evaluation needs to be dynamic in nature and reflect the continuous NMP innovation trajectory model with activities evolving over time.

Consequently, ***for the initial project assessment, as well as monitoring and final evaluation to be successful, the notion of the continuous and evolutionary nature of innovation activities needs to be put in the central position***. Figure 5-1 presents a proposed framework for NMP innovation project cycle based on the study findings. The framework includes eight types of innovation activities as presented before:

(1) Research;
(2) Interaction with users, designers and engineers;
(3) Exploring market opportunities;

(4) Protecting and managing IPR;
(5) Prototyping and industrial demonstration;
(6) Product trials and sales;
(7) Industrialisation;
(8) Innovation management.

The framework for project selection, monitoring and evaluation needs to be linked to Technology Readiness Levels.

As mentioned before, the evolving activities can be linked to specific Technology Readiness Levels (TRLs). This internationally recognised and industrially applied concept outlines in detail the different research and deployment steps, which support the innovation and industrialisation process of technologies to transform ideas to the market[70] (for more information on the essence of TRLs, the reader is advised to consult section 3.2.6 of the current report). The need to align the EU RDI activities with the TRL scale was also one of the key recommendations in the Final Report of the High Level Expert Group on Key Enabling Technologies[71].

For the TRL scale to be effectively adopted by the Project Officers (hereafter "POs") and Project Technical Advisers (hereafter "PTAs"), there is a clear need for ***targeted training sessions outlining the essence of the TRL scale***, as well as its applicability to specific technologies and to the initial FP7/H2020 project assessment, monitoring and final evaluation.

The framework for project selection, monitoring and evaluation needs to assess different aspects at different stages of the innovation's development. These aspects can be captured by analysing the presence of phase-specific success markers.

Additionally, all activities can be split in three main phases that are aligned with the recommendation in the Final Report of the High Level Expert Group on Key Enabling Technologies[72]: (1) Technological Research (TRL 2-4); (2) Pilot Line and Demonstrator Activities (TRL 5-8), and (3) Manufacturing and Deployment Activities (TRL 9).

Each activity and each of the three phases can be further operationalised into a set of specific ***success markers*** or factors common among commercially successful NMP innovations (see Chapter 4 for a detailed overview). Success markers aim to show what proves to be vital in determining whether an innovation will be successful on the market or not, and consequently ***indicate areas that require special attention from the policy makers' side***.

[70] Final Report on Key Enabling Technologies by the High Level Expert Group (2011), available at http://ec.europa.eu/enterprise/sectors/ict/files/kets/hlg_report_final_en.pdf
[71] http://ec.europa.eu/enterprise/sectors/ict/files/kets/hlg_report_final_en.pdf
[72] http://ec.europa.eu/enterprise/sectors/ict/files/kets/hlg_report_final_en.pdf

Similarly to the TRL scale, for success markers to be effectively adopted by the POs and PTAs, there is also a need for ***targeted training sessions outlining the essence of the success markers***, as well as their applicability to specific technologies and to the initial FP7/H2020 project assessment, monitoring and final evaluation.

We need to emphasise here that the presence of success markers per se does not necessarily guarantee the innovations ability to cross the "valley of death" and its subsequent success on the market. They do, however, significantly increase the chance of a positive outcome when compared with cases where such markers cannot be identified. Consequently, to improve the results in terms of exploitation, the identified success markers would need to be integrated into the FP7/H2020 project cycle.

The proposed framework allows for ***screening for different success markers at different phases of the evolving innovation, while constantly addressing the same types of activities*** (e.g., research, innovation management etc.). Consequently, at each phase of the innovation's development, the screening is focused on the markers that matter most for the innovation's success at that particular phase. ***That would allow the criteria of the initial FP7/H2020 project assessment, as well as monitoring and final evaluation to be fully aligned with the key predictors of the future commercial success at different points in time***.

New Production category needs to be treated differently than New Products and Materials.

Finally, as mentioned in Chapter 4, in case of New Production, one has to deal with different types of activities, decisions and challenges when compared with New Products and New Materials, and ***these differences should be taken into consideration when developing effective criteria for the initial FP7/H2020 project assessment, as well as monitoring and final evaluation*** (see Chapter 4 for a proposed set of specific success markers for New Production).

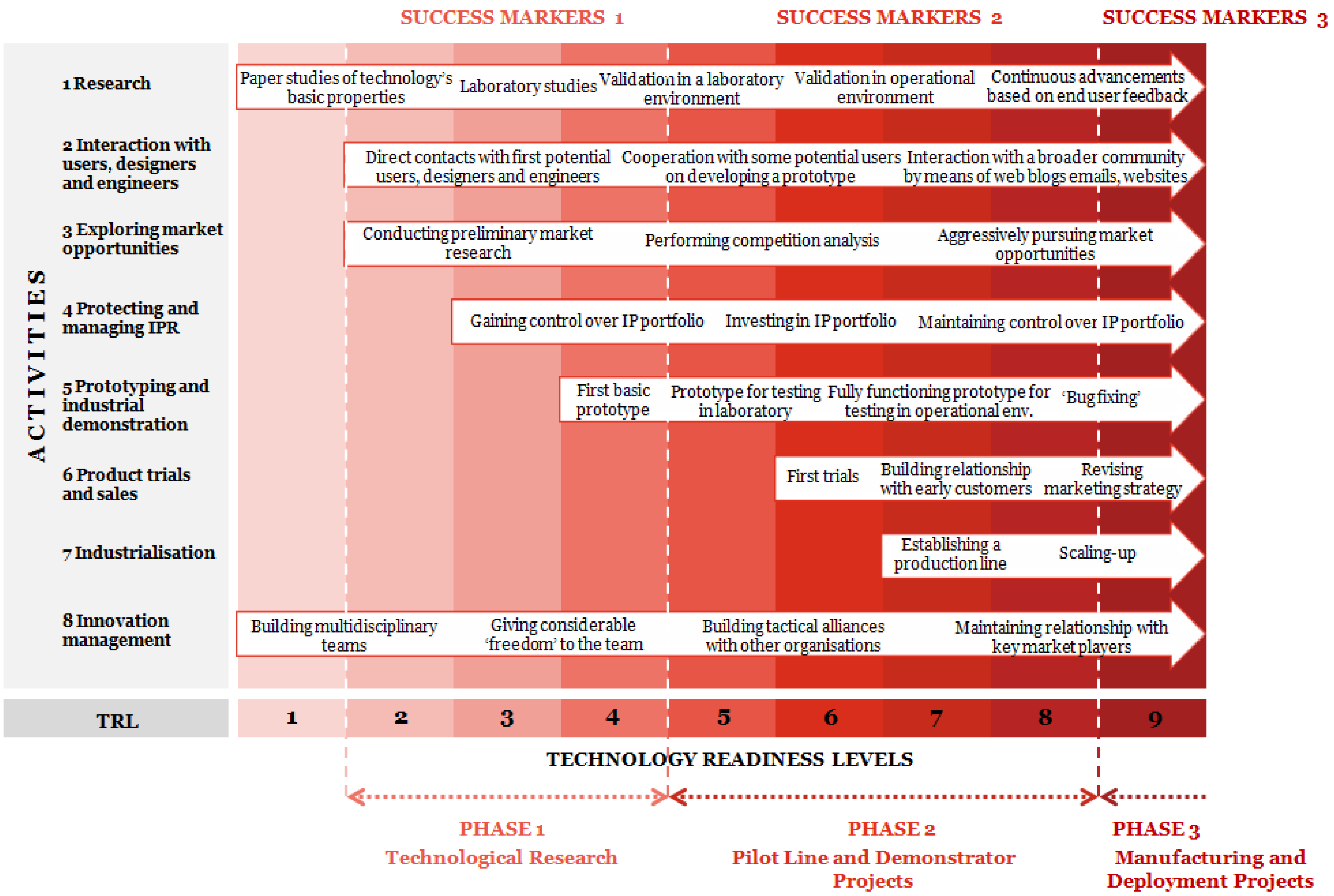


FIGURE 5-1: Proposed evidence-based systematic framework for NMP project selection, monitoring and evaluation

5.1.3. Developing a standardised point system

To enable objective comparisons between projects, a standardised point system needs to be developed, including thresholds.

The identified success markers suggest to be strong predictors of the innovation's success. However, it is important to mention that they represent a *universalistic* (or standardised) set of criteria. From a theoretical perspective, they are expected to be applicable to all potentially successful cases, while in practice, not all potentially successful cases do necessarily satisfy all the criteria. Furthermore, the same criterion can be satisfied to a different extent by different cases. Therefore, measurable indicators need to be assigned to the success markers to ensure an objective assessment.

We suggest the next step to involve operationalising the success markers into measurable items. These items can be measured in actual numbers (e.g., nr of potential users involved in developing the prototype) or in the form of a scale (1 – totally inapplicable to this project; 3 – partially applicable to this project; 5 – fully applicable to this project). This approach allows for developing a point system, with sub-total scores per project activity, and total scores per project phase. ***Establishing thresholds would allow for detecting projects that are well on track, as well as the ones that are off the trajectory potentially leading to commercial success***. Such information, in turn, would provide an objective basis for funding-related decisions.

5.1.4. Communicating the new framework to Project Partners

The new framework needs to be clearly communicated to Project Partners via dedicated tools and initiatives (e.g., Guides for Applicants, ESIC, DG RTD NMP Innovation Platform).

To ensure a full alignment between the expectations of project evaluators and the actions of Project Partners, the identified success markers have to be effectively communicated to the Project Partners well in advance. Not only do these success markers represent a tool for the evaluators, they also ***serve as guidelines for Project Partners with regard to the key actions that need to be taken at each phase to ensure a commercial success of their innovation in the future***. The success markers specify the ways and conditions for transfer of knowledge from research projects to the market, as well as on how to ensure the marketability of innovations.

Chapter 3 of the report provides detailed insights into how the NMP innovation trajectories need to be managed in order to maximise the chance of commercial success in the future. These insights represent lessons learned from the NMP innovations from all over the world that 'did make it to the global market', i.e., valuable knowledge that can assist Project Partners when choosing the approach for their own innovation. Consequently, the whole Chapter 3 of this report can be considered a set of operational recommendations to Project Partners (e.g., entrepreneurs, research centres) on how to improve their entrepreneurial strategies and capacities in Framework Programme projects.

Three key recommended ways of communicating success markers to Project Partners by DG RTD include the following:

- Incorporating success markers into FP7/H2020 Guides for Applicants;
- Incorporating success markers into ESIC[73] (Exploitation Strategy and Innovation Consultants) support programme; *and*
- Disseminating the information on success markers via RTD NMP Innovation Platform[74].

Below we elaborate on each of the abovementioned initiatives in more detail.

The FP7 *Guides for Applicants* contain essential information to guide Project Partners through the mechanics of preparing and submitting a proposal. There are different Guides for different calls, there are also different Guides for the other funding schemes within the same call. If success markers are incorporated into the initial project assessment, then those need to be included in the section of the Guide outlining the evaluation criteria and specific procedures to be applied to proposals in a particular call.

ESIC represents a key programme of DG RTD aiming to secure and enhance the positive impact of NMP projects in terms of exploitation and innovation. The programme implies a tailored assistance to projects through a framework contract provided by external innovation experts. NMP projects are offered this service for free.

Two key ESIC services that could particularly benefit from the findings of the current study include:

- *Project Risk Analysis*: a report identifying the risks for a project that future results will remain unexploited. As presented above, the current study identified a set of markers that indicate a higher chance of successful exploitation of research results. These markers correspond to various stages of the innovation's development cycle and are presented in a form of evidence-based framework. The

[73] http://ec.europa.eu/research/industrial_technologies/pdf/research-innovation/support-nmp-projects-dgrtd_en.pdf
[74] http://ec.europa.eu/research/industrial_technologies/key-factors-on-innovation_en.html

latter allows for keeping track of factors vital for the success of an NMP innovation at each phase and consequently for mapping potential risks related to the absence/insufficient presence of these factors. The results of the study thus form a base for a risk mapping tool for NMP innovations, which if integrated into the current methodology of ESIC Project Risk Analysis, would lead to a structured, empirically confirmed and integrated approach towards risk assessment of NMP projects.

- *Exploitation Strategy Seminars (ESS)*: brainstorming with Project Partners to launch an action plan for addressing the identified risk factors. After assessing the risks related to the absence/insufficient presence of these factors (see the point above), the results of the analysis provided in Chapter 3 of this report could be used for identifying the ways of how these risks could be addressed. It is important to note that examples provided in this report of how successful projects managed to mitigate particular risks are of purely illustrative nature, and there is no one universalistic way of dealing with a certain risk (i.e., no 'one size fits all' approach). The choice of an approach depends, among others, on the type of NMP innovation, its application sector, competition etc. This report, however, illustrates the ways of how diverse NMP projects dealt with the challenges they faced, and thus provides an indication of what possible solutions could be. Tailoring these solutions to the needs of a certain NMP project within the ESIC programme would then be the task of ESIC innovation experts together with Project Partners.

Additionally, the findings of the study could extend the informative base of the *RTD NMP Innovation Platform*. This online platform among others disseminates the results of the analysis of previous NMP projects, and specifically technological and non-technological 'exploitation factors' that prove to be key to overcome the "valley of death" between research outcomes and access to market. The current study collected information from projects/companies that already 'made it' to the market with minimum or no involvement of public funds, and that demonstrated high commercial performance. The study therefore presents a view from the 'other side' (i.e., market side) on how NMP innovations can best cross the "valley of death", which could be a valuable addition to the analysis of publicly-funded NMP projects currently provided by the Platform.

5.2. Recommendations on supporting technology push of NMP innovations

The recommendations presented in this section focus on the following aspects:

- Funding innovation cycle in multiple phases;
- Extending funding towards closer-to-market activities;
- Supporting high-tech SMEs with a new SME Instrument.

5.2.1. Funding innovation cycle in multiple phases

Although the innovations analysed in this study did not signal any significant challenges with regard to obtaining the necessary funding, in general, it proves to be more the exception than the rule. Our finding can be explained by the fact that we were looking at the best practices, the sample which can hardly be considered as consisting of typical representatives of NMP innovation projects. At the same time, the current recommendations aim to refer to a broader pool of NMP innovations, and therefore, the funding issue is brought to the discussion here.

Public funding needs to cover the whole innovation cycle (up to TRL 8), from support to basic science and major research infrastructures to the promotion of open markets for new innovative products.

The financing of the innovation cycle is normally divided into three main phases: (1) funding of 'blue sky' or basic research and development (currently funded by FP7); (2) funding of activities related to demonstration and early introduction to the market (currently funded by FP7 and CIP[75]), and (3) funding of the commercialisation of a new product or service. The first phase is typically covered by public funds as, due to the risky nature of innovation and uncertain economic returns, it is difficult to attract private investment at this stage. Private investors usually enter during the second and third phases. Consequently, ***public funding typically decreases throughout the innovation cycle, with an opposite trend for private funds. At the same time, the costs associated with the innovation cycle increase steadily from basic research up to product development***. Costs for post-research activities, i.e., testing, validation, field trials, pre-development, are typically between 10 to 20 times higher than those of stand-alone research, which creates the famous "valley of death".

Under the previous FPs, thousands of projects have been supported, providing primarily phase one and phase two funding. Within FP7, so called Collaborative Projects (CP) distinguish between "Small and Medium-

[75] Competitiveness and Innovation Framework Programme, see http://ec.europa.eu/cip/

scale focused Research Projects" and "Large-scale Integrating Projects". Funding covers activities in research, demonstration, training, innovation, dissemination and management. FP projects have a typical duration of 3-4 years which is often not enough to go through all stages of the innovation cycle, from basic research and development to the competitive market. The total length of innovation cycle depends on the sector and the type of innovation, but for highly complex technologies (such as NMP), it often is 15 to 20 years long if we take basic research into account and implies high capital intensity. Hence, ***NMP innovations require a consistent multi-year programmatic approach split into several phases*** (see Figure 5-1).

A phased approach towards funding would stimulate higher performance of funded projects and ensure higher flexibility for both Project Partners and policy makers.

Additionally, different innovation cycle phases (research vs. exploitation) often require the involvement of different types of partners (universities and research institutes vs. Technology Transfer Offices (TTOs), suppliers, downstream industrial partners). A ***phased approach towards funding*** could allow changes in the composition of the consortia with each new phase of the project, i.e., by the end of a phase, some actors could voluntarily exit the project if their contribution was finished, while new actors (upper part of the value chain) could enter[76].

Consequently, in order to put Europe at the forefront of knowledge-based economy, ***the new approach needs to cover the whole innovation cycle, from support to basic science and major*** research ***infrastructures to the promotion of open markets for new innovative products***, thereby making full use of regulations, standards, public procurement and intellectual property rights[77].

5.2.2. Extending funding towards closer-to-market activities

FP and Horizon 2020 programmes should support closer-to-market activities including prototyping, testing, demonstration and validation (TRL 6).

The evidence from the study shows that there is a clear need for extending the scope of funding towards closer-to-market activities including prototyping, testing, demonstration and validation (TRL 6)[78]. The same need has been emphasised in the Final Report on Key Enabling Technologies by the High Level

[76] See also PwC's report on "EU budget support for research and innovation" prepared for the Directorate General for Internal Policies of the European Parliament, June 2012, available at http://www.europarl.europa.eu/committees/en/cont/studiesdownload.html?languageDocument=EN&file=74671

[77] See also Horizon 2020 - The Framework Programme for Research and Innovation - Impact Assessment Report, pp. 24-25

[78] See also http://ec.europa.eu/atwork/synthesis/amp/doc/rtd_mp_en.pdf

Expert Group (2011)[79] stating that ***the future KETs programme should fully support closer-to-market activities along with the supporting infrastructures (technological platforms and pilot lines along with first-in-kind equipment and facilities)***.

Extending funding towards closer-to-market activities implies different requirements for participating consortia. ***Already at the proposal stage, Project Partners should be encouraged to address the issues of the exploitation and market take-up of innovative solutions. Specific issues to be addressed include preparing exploitation strategies and roadmaps, cost-benefit analysis, as well as identifying future funding opportunities, niche markets, barriers and bottlenecks, and business models***.

With regard to the funding of the third phase (see sub-section 5.2.1), the RSFF[80] and the CIP-connected horizontal instruments (GIF and SMEG) are reported to demonstrate clear benefits. They are suggested to offer solutions in cases where market failures occur with respect to the financing needs of some SME categories like small firms in the first expansion phase, and high growth SMEs in further expansion stages[81]. Consequently, there is a need to build on these instruments in order to facilitate access to risk finance and venture capital. This recommendation is already reflected in the proposal for "Access to risk finance" instrument within Horizon 2020[82] and is supported by the findings of this study.

5.2.3. Supporting high-tech SMEs with a new SME instrument

The criteria for project selection, monitoring and evaluation for high-tech SMEs should be driven by the market realities of those SMEs.

The abovementioned needs (i.e., covering the full innovation cycle including closer to market activities and applying a phased approach) are already reflected in ***a new SME instrument to be launched under Horizon 2020***. The instrument aims to fill the gaps in funding for early-stage, high-risk research and innovation by SMEs, as well as stimulating breakthrough innovations. Support will be provided in three different phases covering the whole innovation cycle (similar to the US SBIR model[83]; see also Section 3.5). A *feasibility part* will allow an assessment of the technological and commercial potential of a project.

[79] Final Report on Key Enabling Technologies by the High Level Expert Group (2011), available at http://ec.europa.eu/enterprise/sectors/ict/files/kets/hlg_report_final_en.pdf

[80] Risk-Sharing Finance Facility, see http://www.eib.org/products/rsff/index.htm

[81] See EC (30/11/2011), *Public Consultation for Horizon 2020*: Written contributions from European organisations received in response to the Green Paper, cross-document analysis of Question16

[82] http://ec.europa.eu/research/horizon2020/pdf/press/horizon2020-presentation.pdf

[83] http://www.sbir.gov/about/about-sbir

A *main grant* will be provided to undertake R&D activities with the emphasis on demonstration and market replication. Finally, the *commercialisation phase* will be supported indirectly through simplified access to debt and equity financial instruments as well as various other measures, for example on IPR protection. The progress of an SME will be evaluated at the end of each phase. Successful completion of one phase will allow an SME to move on to the next, each phase will be open to all SMEs[84]. This new instrument will synergise with the existing RSFF[85] and the CIP[86]-connected horizontal instruments (GIF and SMEG) facilitating access to risk finance and venture capital. The findings of the current study provide additional justification and confirm a clear need for this new instrument.

In Chapter 4, we presented a set of success markers specifically developed for the needs of SMEs. These markers are likely to be of high relevance for the new SME instrument as evidenced by the citation below.

> The need for business-oriented evaluation criteria for the SME instrument[87]: "*The SME instrument should take account of investors' realities, be selective and competitive to establish its credibility with the market. This requires defining SME-specific and transparent evaluation criteria that are business-oriented and focus on commercialisation potential. Evaluators need to understand business and markets as well as being technology and innovation savvy. The staged scheme with evaluation at each step should allow promoting only the best projects ('quality label'). R&I results that come out of this selection process should have a good chance to succeed in the market and to raise equity.*"

The framework with success markers developed by this study could thus form the base for the monitoring and evaluation activities of the SME instrument, the activities that inevitably need to be put in place to be able to judge on the progress (monitoring) and success (evaluation) of each phase (i.e., feasibility phase; R&D including demonstration and market replication; and commercialisation phase). As mentioned above, measurable indicators need to be assigned to the success markers to ensure an objective assessment which implies operationalising the success markers into measurable items. These items can be measured in actual numbers (e.g., nr of potential users involved in developing the prototype) or in the form of a scale (1 – totally inapplicable to this project; 3 – partially applicable to this project; 5 – fully applicable to this project). This

[84] http://ec.europa.eu/research/horizon2020/pdf/press/fact_sheet_on_sme_measures_in_horizon_2020.pdf
[85] Risk-Sharing Finance Facility, see http://www.eib.org/products/rsff/index.htm
[86] Competitiveness and Innovation Framework Programme, see http://ec.europa.eu/cip/
[87] Summary Report on the workshop on "New Approach to SME support in Horizon 2020: implementation challenges and good practices", Brussels 23 April 2012, available at http://ec.europa.eu/research/sme-techweb/pdf/new_approach_workshop_report.pdf

approach allows for developing a point system, with sub-total scores per project activity, and total scores per project phase. ***Establishing thresholds would allow for detecting projects that are well on track (i.e., with a good chance to succeed in the market and to raise equity), as well as the ones that are off the trajectory potentially leading to a commercial success***. Such information, in turn, would provide an objective basis for funding-related decisions.

Finally, to best support the technology push of NMP innovations, the abovementioned new or advanced instruments should be complemented by the use of existing instruments that have already proven to be successful, e.g., RSFF instrument mentioned above. The objective of RSFF is to improve access to debt financing for all types and sizes of private companies undertaking RDI projects. The scope of eligible activities includes infrastructure, equipment, salaries (researchers, management and support staff), utility bills, consumables, acquisition and protection of Intellectual Property Rights and, under certain conditions, leasing and depreciation. The programme is a joint effort of the European Investment Bank (EIB) and the European Commission[88].

5.3. Recommendations on supporting market pull of NMP innovations

The recommendations presented in this section focus on the following aspects:

- Encouraging interaction with end-users;
- Going beyond technological innovation;
- Stimulating (pre-commercial) public procurement;
- Enhancing the link between regulation and innovation.

5.3.1. Encouraging interaction with end-users

As emphasised in the analysis part of the report, successful NMP innovations prove to demonstrate an ***active involvement of a broad community of users, designers and engineers from the very beginning of their innovation trajectory and throughout the whole cycle***. This involvement may take different forms such as:

- online collaboration platforms with a broader community (e.g., websites where people from all over the world are invited to submit their product designs, work on the improvement of a certain technology or production process);

[88] http://www.eib.org/products/rsff/index.htm

- direct contacts with users, designers and engineers at company's premises, conferences, fairs and/or other events;
- interaction with a broader community by means of web blogs and emails (the current study confirmed that the best way to reach technology enthusiasts is to place a message on the Internet; direct email will reach them too, and provided it is factual and contains new information, they will read it cover to cover);
- engagement in open source approach (although this measure is not typical for all analysed cases, and some companies still find it too risky; companies that managed to benefit from open source approach share with public domain only some elements of their technology, protecting the rest in the form of IP or trade secrets).

Funding instruments need to encourage early interaction with end-users which proves to be decisive for commercial success.

Interaction with end-users strengthens the innovation's ability to quickly adapt to new market demand or circumstances. The feedback provided by the end-users signals the areas where rapid improvement is needed, and of that information is taken onboard, the likelihood of commercial success considerably increases. Consequently, ***interaction with end-users should be encouraged within FP7/H2020 projects in order to enhance short- to medium-term market impacts***[89]. An approach towards the interaction with end-users should be already sketched in the initial project proposal and embedded in project planning. It should also form the part of the proposal assessment.

5.3.2. Going beyond technological innovation

Funding instruments need to include the non-technological aspects of innovation such as design, creativity, service, communication, processes, business models.

As confirmed by this study, treating NMP innovations purely as technological innovations means omitting a large part of the complexities associated with such innovations (e.g., the need to 'prepare' the market mentally for the arrival of a radical innovation; the need to educate the users with regard to how to exploit a particular innovation etc.). Therefore, for KETs in general and NMP innovations in particular, there is a need to embrace a broader concept of innovation, including its non-technological aspects such as design, creativity, service, communication, process and business model innovation. All these aspects refer to so called ***social innovation***[90]. Social innovation implies new ideas (products, services and

[89] This recommendation is in line with one of the recommendations of the report on "Ex-post Evaluation of FP6 (NMP): Project Level" (2011), available at http://ec.europa.eu/research/industrial_technologies/pdf/ex-post-evaluation-fp6-nmp-2011_en.pdf

[90] See also EC (2011), *Green paper on a common strategic framework for EU research and innovation*: Analysis of public consultation, p.24

models) that simultaneously meet social needs more effectively than alternatives and create new social relationships or collaborations[91].

Similar to NMP technological innovation, social innovation is cross-disciplinary and multidimensional. At the same time, it implies deep synergies with other intangible assets such as human capital, social capital, information systems, clients, stakeholders, brand and reputation. Furthermore, it is user-driven innovation instead of research-driven innovation[92]. Social innovation goes hand in hand with NMP technological innovation, and proves to be decisive for successful market entry and commercial growth.

The aspects of social innovation therefore need to be included in the evaluation of the quality of the future NMP projects, including project selection. Specifically, such aspects could refer to strategies of communicating with potential users, activities aimed at educating the public about the essence of a particular innovation and its features and application areas, as well as innovative business models to accelerate commercial success.

5.3.3. Stimulating (pre-commercial) public procurement

As mentioned before, some of our non-European cases owe their success to the public procurement. For example, an American case Silverlon (wound care dressing) emphasised the role of the U.S. Army in testing during the Iraq and Afghanistan wars, and then massively buying the final product.

Pre-commercial public procurement represents a powerful tool for the creation of lead markets, boosted industrial innovation, better performing government and solutions to societal problems.

Purchasing innovative solutions at public sector level is suggested to lead to the creation of lead markets, boosted industrial innovation, better performing government and solutions to societal problems. Pre-commercial public procurement ensures (early) market adoption and stimulates local sales. Moreover, it may give other companies an incentive to be early adopters given that a certain technology has already found its way to the market. Consequently, by acting as technologically demanding first buyers of new R&D, public procurers can drive innovation from the demand side. This enables public authorities to advance the provision of public services faster and creates

[91] NESTA and The Young Foundation (2010), Murray R., Caulier-Grice J., and Mulgan G., *Open Book of Social Innovation*, p. 224

[92] See also PwC's report on "EU budget support for research and innovation" prepared for the Directorate General for Internal Policies of the European Parliament, June 2012, available at http://www.europarl.europa.eu/committees/en/cont/studiesdownload.html?languageDocument=EN&file=74671

opportunities for companies to take international leadership in new markets[93].

This approach is already widely used in the United States and Japan as an important mechanism to stimulate innovation. Pre-commercial public procurement has also been recently introduced in Europe[94] and needs to be expanded.

Pre-commercial public procurement needs to be based on a sectoral approach as its relevance varies per application sector.

Two conditions are reported to be necessary here: a coherent policy and a professional public procurement process. A coherent policy implies a procurement policy that is an integrated part of the general innovation policy and that addresses all the relevant (government) stakeholders and encourages them to purchase new innovations. A professional public procurement process, in turn, means structuring organisation, knowledge, and incentives in order to make procurement of innovation possible[95].

Pre-commercial public procurement is, however, not equally relevant for all industrial sectors. It should therefore not be viewed as a possible solution for the whole category of NMP innovations. The NMP application sectors where public needs have always been an important driver of innovation and thus where pre-commercial public procurement is likely to play an important role include ***telecom, energy, health, transport, security and defence***[96]. The procurement of R&D in these sectors allows to address common public needs for which no solution exists on the market. Other sectors such as, for example, textiles, are less related to the global public challenges and thus less likely to be stimulated by means of pre-commercial public procurement. Consequently, when developing pre-commercial public procurement measures for Europe, a ***sectoral approach*** needs to be applied, where sectors should refer to the application areas rather than technology areas.

Key challenges concerning pre-commercial public procurement at the EU level are:

- Creating awareness among SMEs about pre-commercial procurement possibilities;
- Improving access to public procurement projects (especially for SMEs);

[93] COM(2007) 799 Pre-commercial Procurement: Driving innovation to ensure sustainable high quality public services in Europe

[94] COM(2007) 799 Pre-commercial Procurement: Driving innovation to ensure sustainable high quality public services in Europe

[95] OMC-PTP (2009), Veys C. et al, EU project Procurement of Innovation: *Exploring Public Procurement of Innovation as a Strategic Innovation Policy Mix Instrument*, p. 82

[96] See also COM(2007) 799 Pre-commercial Procurement: Driving innovation to ensure sustainable high quality public services in Europe

- Better planning of government procurement that would help to address some of the problems suppliers face, by offering greater scope for capacity planning[97]; *and*
- Low pre-commercial procurement budget for the EU, in comparison with the United States, for example, due to[98]:
  - Lack of awareness on how to optimise risk-benefit balance for procurer and supplier;
  - Lack of knowledge of how to fit this within the legal framework for R&D procurement; *and*
  - Fragmentation of demand.

In the Horizon 2020 proposal, pre-commercial procurement is already officially introduced as a new funding instrument that can be used across all areas of research and innovation supported by the Commission. The proposal foresees the possibility for the EU to financially support pre-commercial procurements undertaken by groups of contracting authorities from different Member States. It also includes the possibility for the EU or EU funding bodies to participate themselves in pre-commercial procurements undertaken together with contracting authorities from Member States[99].

5.3.4. Enhancing the link between regulation and innovation

With the help of regulation policy makers can encourage R&D, increase the possibilities of practical application, and ensure public acceptance.

KETs are considered to be essential for solving grand societal challenges in the fields such as energy, climate change, healthcare, security, etc. A grand challenges approach is now widely accepted in European policy making, and it is going to be one of the key principles guiding Horizon 2020[100]. At the same time, the current study showed a significant role of regulation on the development of KET innovations. Consequently, regulation plays a central role in stimulating the solutions for the grand societal challenges.

That ***regulation may act as an accelerator for the innovation's introduction to the market*** was illustrated by several analysed cases, for example, Advanced Marine Coatings and tripleO. These innovations have a direct link to environmental regulation. In case of tripleO, evidence was found that the coating reduces drag by up to 39% on a coated surface. By reducing drag, motorised solutions, such as aircrafts or cars,

[97] "Innovation report, competing in the global economy: the innovation challenge", DTI, December 2003, available at: http://webarchive.nationalarchives.gov.uk/+/http://www.dti.gov.uk/files/file12093.pdf
[98] Bos, L. (2008) "Pre-commercial procurement, driving innovation to ensure high quality public service in Europe", available at: ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/pcp/20090616-lieve-bos_en.pdf
[99] http://cordis.europa.eu/fp7/ict/pcp/policy_en.html
[100] http://ec.europa.eu/research/erab/pdf/erab-study-grand-challanages-2012_en.pdf

become more fuel efficient as the engines have to compensate for less friction. With environmental regulation becoming increasingly more stringent and with airlines trying to minimise their carbon footprint, tripleO was provided a great opportunity to market their product. The company could emphasise the environmental friendliness of the product while offering clear-cut benefits in both a higher fuel efficiency itself and a subsequent reduction in carbon dioxide emissions.

Besides being an accelerating factor, ***regulation can also become a significant barrier for the innovation to enter the market***. For example, European environmental legislation aims at banning certain semiconductor materials which contain arsenic from the European market, which, in turn, proved to be highly unfavourable for the DFB laser case.

Policy makers are constantly challenged to make decisions on further priorities of publically funded research and on regulation. In order to respond to the society's concerns, it is of crucial importance to maintain a dialogue on benefits and risks of NMP innovations, including ***ethical, legal, societal aspects*** as well as ***environment, health and safety*** aspects, involving great parts of the public and basing on informed judgement. At the same time, ***when recognising the potential societal and economic benefits of NMP innovations, policy makers need to encourage R&D, increase possibilities of practical application, and ensure public acceptance.*** Regulation in this case represents a powerful tool to achieve these objectives.

Finally, the link between standards and innovation should also be considered. Existing research shows that standards can help to foster the diffusion of new technologies and the emergence of new markets[101]. Standards allow for reduction of information, transaction and adaption costs; ensuring interoperability between components; as well as for achieving increased quality of products and reduced health and safety risks[102].

Project Partners within FP7/Horizon 2020 programmes can play an important role in the evolution of existing standards or in stimulating the

The current study demonstrated that teams developing innovations set the newest technology trends and generate valuable knowledge that rapidly needs to be taken up by the standardisation and regulatory systems if Europe aims to be at the forefront of the knowledge-based economy. Consequently, there is a clear need for expanding the role of standards in the European regulatory framework by taking into account issues brought up by various stakeholder groups[103]. It implies ensuring

[101] Based on Blind K. (2006) "Innovation and Standards", Europe INNOVA Thematic Workshop on Lead Markets and Innovation, June 29th and 30th, 2006, Munich, Germany

[102] See INTEREST project "Integrating Research and Standardisation", http://cordis.europa.eu/documents/documentlibrary/124857051EN6.pdf

[103] See also Blind K. (2006) "Innovation and Standards", Europe INNOVA Thematic Workshop on

that (publicly funded) research results are effectively and efficiently transferred into standardisation processes. In this respect, Project Partners within FP7/Horizon 2020 programmes can play an important role in the evolution of existing standards or in stimulating the development of new standards. It would be recommended to integrate standards and standardisation already in project proposals which can also amplify the impacts of those projects, as well as facilitate the dissemination and exploitation of research results[104].

Lead Markets and Innovation, June 29th and 30th, 2006, Munich, Germany

[104] See also http://www.cencenelec.eu/research/fp7areas/Pages/default.aspx

Annex A: Concise case study descriptions

Case study descriptions are presented in the following order:

Fieldwork I and II ***Name***	***Region***	***Country***
I New products (10)		
I.1 New products: Intermediates (5)		
(1) FII.I.1.3 Advanced Marine Coatings	Europe	Norway
(2)FII.I.1.1 DFB laser	Europe	Germany
(3) FII.I.1.2 Envirox™	Europe	United Kingdom
(4) FII.I.1.4 Triple O Performance Solution	Europe	United Kingdom
(5) I.1.B.2 Ultra Compact Femtosecond Fiber Laser PFL-200	East Asia	Japan
I.2 New products: End products (5)		
(6) I.2.B.3 APADENT and APAGARD Nanohydroxyapatite Toothpaste	East Asia	Japan
(7) I.2.A.7 NAO robotics research platform	Europe	France
(8) I.2.A.6 Q.E.F. Electronic Innovations Epilepsy Bracelet	Europe	Netherlands
(9) I.2.C.1 Silverlon Wound Care and Surgical dressings	North America	United States
(10) FII.I.2.1 T-Sight 5000	Europe	Italy
II New materials (10)		
(11) II.A.8 Crystalsol flexible photovoltaic technology	Europe	Austria
(12) II.B.1 Glow in the dark powder	East Asia	Taiwan
(13) FII.II.4 It4ip	Europe	Belgium
(14) FII.II.2 Kriya Materials B.V.	Europe	The Netherlands
(15) FII.II.1 NKR® single crystal alumina fibers	Europe	Spain
(16) II.A.4 Oerlikon diamond coatings	Europe	Luxembourg
(17) FII.II.6 Poss®	North America	United States
(18) FII.II.5 Régéfilms Sud Ouest	Europe	France
(19) FII.II.3 SA Envitech s.r.l.	Europe	Czech Republic
(20) II.A.7 Technically Hybrix™ sandwich material	Europe	Sweden
III New Production (10)		
III New Production: New Industrial Models and Strategies (5)		
(21) FII.III.1.3 GBL - Fermentation Process	Europe	United Kingdom
(22) III.1.C.1 Local Motors crowdsourced car manufacturing	North America	United States

Fieldwork I and II		
(23) III.1.C.2 MakerBot 3D printer crowdsourced manufacturing	North America	United States
(24) FII.III.1.2 Nulife Glass, separation and extraction of lead from CRT waste	Europe	United Kingdom
(25) FII.III.1.1 Rhodia, recycling rare earth material from luminescent powders	Europe	France
III New Production: Adaptive Production Systems (3)		
(26) FII.III.2.1 DyeCoo's liquid CO2 textile dying process	Europe	The Netherlands
(27) FII.III.2.2 Resteel	Europe	The Netherlands
(28) FII.III.2.3 Ricoh's cart production line	East Asia	Japan
III New Production: Networked Production (2)		
(29) FII.III.3.1 Liquisort, magnetic density separation (MDS)	Europe	The Netherlands
(30) III.3.A.1 Ponoko's user manufacturing platform	East Asia/Pacific	New Zealand

Advanced Marine Coatings

Category:
New Products

KETs involved:
Nanotechnologies

Country:
Norway

Year of market entry:
2007

Time from research to market:
Field trials: 1 year
Full sales: 4 years

Availability on the market:
Globally

What made this case interesting for this study:
The development of the innovation was spurred by an existing discovery. By acquiring the patent, the company found a way to develop their product and commercialise innovative technology. Moreover, the case underlines the importance of field trials in both the development of the product and its commercialisation.

Website:
http://www.amcoat.no

Short case description

Advanced Marine Coatings AS (AMC) is a pioneer in using carbon nantubes (CNT) in marine coatings. The company has developed marine coatings by combining carbon nanotubes (CNT) with a patented dispersion technology. The resulting coatings exhibit exceptional abrasion resistance and smoothness. The use of these leads to significantly reduced fuel consumption and increased ships' speed. Moreover, they have a minimal environmental impact when compared to traditional epoxy-based coatings.

Currently, AMC produces a large array of marine coatings for diverse application areas such as for decks and topsides, ballast tanks et cetera. The coatings are sold world-wide through the company's website and in some countries through distributors. The company continues to improve on the coatings.

Innovation cycle

In 2005, the founder of the company was inspired to develop the coatings after learning about a discovery made by a Finnish company. The discovery was associated with the use of CNT in polymers. This would form the basis of the innovation.

In 2006, the company did research and conducted a few tests to understand the effect of using CNT in epoxy-based coatings. The company faced a difficulty here in dispersing CNT in liquids. To counter this problem, the company partnered with Amroy Oy, a Finnish company, which has a patented dispersion technology. The company licensed the technology and now holds exclusive worldwide rights to use the key patent on which their marine coatings have been developed.

After acquiring the patent, extensive research work was carried out during the first three years. AMC tested different formulations of the product. It also tested a large number of factors such as anti-corrosion properties of the coatings, effect of Ultraviolet light on the coatings, effect of immersion below the water line and so on.

The company initiated their first field trial of the product in Autumn 2007. A series of field trials subsequently took place in 2009, 2010 and 2011 at various companies, and are still on-going in Norway. AMC conducted trials on different types of boats with vessels of up to forty meters in length. These tests demonstrated an increase in speed of between six to ten percent, or a corresponding reduction in fuel consumption.

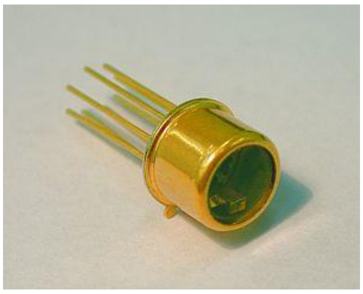
Currently, a large number of field trials are being conducted for different customers. Some of these customers have already proceeded to procure AMC's coating commercially. The company is holding negotiation talks with other companies in the marine market in the Nordic region, but plans to expand its coating offerings to other geographical areas.

Highlight of the case

The coating developed by AMC has a minimal environmental impact. This has helped the company in dealing with, and in some cases circumventing, specific regulatory issues.

In fact, regulation could even be identified as a positive factor, specifically for the dissemination of the innovation. As the coating can reduce fuel consumption of marine vessels, it allows marine companies to decrease their carbon footprint. With increasingly stringent regulation on environmental impact, coatings like AMC have increasingly become more in demand.

Distributed Feedback (DFB) Laser



Category:
New Products

KETs involved:
Photonics; nanotechnology

Country:
Germany

Year of market entry:
1999

Time from research to market:
About 4 years

Availability on the market:
Nanoplus, the German spin off company selling the DFB laser, offers the laser to a global market.

What made this case interesting for this study:
The DFB semiconductior laser is a laser variant which is unique because it only emits one specific colour. Nanoplus sells a laser that has unique and new-to-the world technology and a range of wavelengths for different applications. There is no other company in the world which sells lasers with such a broad range of wavelengths and as a result application possibilities.

Website:
http://www.nanoplus.com/index.php

Short case description

Singlemode distributed-feedback (DFB) laser diodes enable gas sensing using tunable diode laser spectroscopy (TDLS), which detects gas species at trace levels in the parts-per-million (ppm) range. Tunable diode laser spectroscopy is a versatile technique for the detailed characterisation of gas compositions. Nanoplus lasers are operating reliably in more than 10.000 installations worldwide including power plants and gas pipelines as well as airborne and satellite applications in sensing and metrology. One of the most famous applications is the use of a DFB laser for gas detection purposes during the latest NASA mission on Mars.

Innovation cycle

The innovation trajectory of the DFB lasers consists roughly of two main steps which can be subdivided into seven steps that correspond to the innovation cycle.

In the first phase fundamental research was conducted by several PhD students at the University of Wurzburg in the state of Bavaria, Germany. The innovation process was technology push in nature, since the PhD students did not have an application in mind. Their findings were eventually commercialised by a spin-out company Nanoplus, also located in Wurzburg. Nanoplus sold the first marketable lasers and also performed further research and development on the DFB lasers to widening the application range of its product. The innovation trajectory has been financed by several parties. The research at the university has been financed by the university. During the start-up phase, Nanoplus was financed mainly through government grants, university support, a bank loan, and contract research and development for companies and institutions.

The DFB laser product range is protected by eight different patents of which three are owned by the company for in-house development. The products of Nanoplus are sold all over the world. Since the DFB laser is an intermediate product, the buyers are usually firms which build the laser into measurement systems, which are the end products. The production of a DFB laser for a NASA mission to Mars has also been a catalyst for an increase of sales, providing Nanoplus with a quality trademark and a lot of exposure.

The main success factor behind the development has been the company-university interaction at several of the earlier stages of the innovation cycle. Moreover the product market strategy of Nanoplus has been conducive to the success of the DFB laser. Early commercialisation without large sales volumes was possible because Nanoplus performed contract research. This was never their core business but helped the company to become self-sustainable and to leverage turnover generated by these activities to research and marketing for their core product. The largest barriers in the cycle were difficulties in optimising the leverage of the technology to products due to a mixture of challenges the company was facing, such as scaling up the production, verification of the products, scale up of personnel and automatisation.

Highlight of the case

Nanoplus has created a new market demand with the introduction of the DFB laser for gas sensing purposes, thereby replacing technologically outdated, inferior methods for gas detection. The company was the first-mover into this market and maintained a strong market position to date, being able to set prices and broadening the application range without much competition.

Envirox™

Category:
New Products

KETs involved:
Nanotechnologies

Country:
United Kingdom

Year of market entry:
2003-2004

Time from research to market:
3 years

Availability on the market:
Global market

What made this case interesting for this study:
The product showcased fundamental new functions and was new to its operating market. The case itself showed the importance of field trials, as many of the potential customers were rather skeptical at first. They first needed to see the performance improvements in practice before committing to the product.

Website:
http://www.energenics.co.uk/

Short case description

Envirox™ is a fuel borne combustion nanocatalyst used in diesel fuel. Envirox™ fuel combustion catalyst is a scientifically and commercially proven diesel fuel additive which lowers fuel costs, by reducing fuel consumption, and also reduces greenhouse gas emissions (CO_2) and other harmful exhaust emissions. These benefits are achieved by using a catalyst technology based on cerium oxide, a well-known industrial catalyst, which is already used within the automotive sector in three-way catalytic converters for gasoline fuel engines.

The product was developed in 2001 by Oxonica Energy Limited, a subsidiary of Oxonica. It was based on a patent owned by Neuftec, a research and development company, registered in the Commonwealth of Dominica. Oxonica licensed the patent to develop Envirox™. Oxonica is a spin-out of Oxford University.

Innovation cycle

After licensing the patent from Neuftec in 2001, Oxonica started its research efforts to develop the key idea in the patent. Around the same year, the company succeeded in producing Envirox™.

The next couple of years were devoted to rigorous laboratory testing of the additive. The additive was tested in a controlled environment.

Laboratory testing was not sufficient to demonstrate the product's benefits to potential customers, hence the company decided to take the product into the field. In 2003-2004, field trials of Envirox™ were conducted in Hong Kong by a company owned by Stagecoach, a large transport company in the UK. The field trials offered proof that the benefits of the product could be established in real-world operations. In the first field trial, the fuel savings turned out to be as high as 10 percent. Following this trial, several other field trials were conducted mainly in the UK.

Parallel to the field trials, Oxonica invested its time and money in conducting tests which were appropriate to share with customers to convince them that the product is beneficial for the users and the public. At the beginning of the development, Oxonica outsourced the manufacturing of the additive to an Australian company. Oxonica offered a standardised product to its customers, hence there was no customised offering of Envirox.

To summarise, during the early years, several major trials were carried out to validate the results of using the product. In total, it took about three years to bring the product from invention to the hands of the first major customer, Stagecoach.

Highlight of the case

To ensure the efficient and the effective use of Envirox™, the company had to provide its customers with enabling equipment. This enabling equipment comprised dosing units which ensured proper mixing of the product in the fuel.

Oxonica worked with an electrical engineering company to make these units. Over the years, the dosing unit has gone through a number of improvements, making it more reliable and automated. They applied the dosing technique during the field trials and kept looking for more reliable dosing techniques to ensure optimal performance of the fuel additive.

tripleO Performance Solution

Category:
New Product

KETs involved:
Nanotechnology

Country:
United Kingdom

Year of market entry:
2007

Time from research to market:
Over 30 years when considering the basic product
About 7 years when considering the nano-enhanced coating (2000-2007)

Availability on the market:
Global market

What made this case interesting for this study:
The coating is a radical new product that can be applied to many existing solutions. It is endorsed by key players in the aviation industry (easyJet, British Airways), even though the technology existed in its basic form already. Continuous improvements, further research and strategic partnerships with key players led to the success of the product.

Website:
http://www.tripleops.com

Short case description

tripleO Performance Solution is a radical new intermediate product that can be applied to many existing solutions. tripleO is a nano-enhanced coating that fills gaps and crevices in paint or topcoat surface finishes. Current applications of the product include commercial airliners, trucks, boats and helicopters, but many more applications can benefit from this coating.

tripleO gained a lot of exposure for coming up with a revolutionary approach for the aviation industry. tripleO reduced friction up to 39%, bringing about a significant reduction in fuel consumption, and with the new improved tripleO a far greater saving can be achieved. In addition, it also protects external and internal surfaces, which has proven to extend the working life of the coated application while also giving it a consistently clean look. Moreover, it achieves a reduction in water consumption and reduces the chemical footprint.

Innovation cycle

The innovation cycle of tripleO has some interesting characteristics. the initial product had a 30 year pedigree and incorporated nanotechnology at the turn of the millennium. However, with the R&D completed by tripleO they have now developed a new improved tripleO with a different chemist in a different factory with improved outcomes. This new tripleO has already gained Airbus and Boeing approval.

The owner of the technology in the U.S. sent out a Google alert in 2007, which announced that a particular product was coming out and that it was seeking commercial exploitation. Paul Booker, managing director of tripleO, subsequently acquired the global rights to commercially exploit the product.

To get the coating to the market, they took several steps: they applied the coating on a smaller airplane to demonstrate it in an experimentation phase, they developed personal relationships with their clients to gain feedback and offer support, and they are continuously researching and improve the product. In 2010, tripleO struck a deal with easyJet to trial the coating on three of their aircraft. They agreed with Easyjet that both parties would carefully evaluate the performance of the coating.

The activities of tripleO then were not limited to commercial exploitation. Although they acquired the technology, they came up with a new process to best apply the coating themselves. Furthermore, they are doing on-going research in collaboration with Kingston

University to understand and improve both the coating itself and how to apply it. This includes extensive wind tunnel testing and laboratory research as well as field trials with customers.

In this point, various airlines have expressed their interest. The company has also coated innovators in other areas, such as a solar panel producer in Silicon Valley, various boats and hair straighteners.

Highlight of the case

The case provides another example of how regulation can help the diffusion of the innovation. Rising fuel costs and increasingly stringent (environmental) regulation offered a landscape for the team to market their product in. As particularly the aviation industry was looking for ways to increase fuel efficiency and reduce their carbon footprint, tripleO filled a void in which a coating can add such benefits overnight.

Femtosecond Fiber Laser PFL-200

Category:
New Products

KETs involved:
Photonics; nanotechnology

Country:
Japan

Year of market entry:
2003

Time from research to market:
12-15 months

Availability on the market:
The PFL-200 laser is available in Asia, Europe, America, Australia and New Zealand.

What made this case interesting for this study:
It was a novel idea to use nanotechnology in laser. It mainly had R&D applications in the beginning. The laser sought a great deal of attention from universities and corporate research labs. Moreover, the laser is commercially successful. It was rapidly introduced to the market. The whole process of basic research and its transition to market took only a few months.

Website:
http://www.alnair-labs.com/index.html

Short case description

The PFL-200, Ultra-Compact Femtosecond Fiber laser is a polarisation maintaining pulsed laser incorporating proprietary carbon-nanotube modelocker. It is a breakthrough product cutting across two disciplines, nanotechnology and photonics. Its applications range from university and corporate research to industrial systems. The laser was first developed in Japan and was first introduced to the Japanese market in 2003.

Innovation cycle

The innovation process of PFL-200 consisted of several steps and feedback loops. The key blocks of the innovation process were: Basic Research, Patent Filing, Marketing, Prototype development, Sales and distribution. Few of the steps were executed in parallel during the course of innovation. PFL-200 was perhaps an outcome of technology push in the beginning. PFL-200 was purely a research project, initiated out of curiosity about incorporating carbon nanotube in lasers. However, in the last few years, its development has become more customer-driven. The first prototype was launched in March 2003. The research was disclosed in public through news releases, magazine columns and interviews. By that time, a provisional patent had already been filed in the US and Japan. It was shown to the University of Tokyo research lab. This was a key success factor. It helped the company to get exposure to the targeted market, as well as R&D labs.

The first commercialisation deal for the laser was made in 2003, with University of Tokyo. The laser was mainly targeted at R&D customers such as university labs. Interpersonal relationships and networking played a central role at this stage.

Alnair Labs Corporation used patents as the prime way to protect its innovation. Right after the invention, Alnair Labs Corporation filed provisional patents in the US and Japan, and later on also in Europe. The company filed provisional patents because it is faster to file such patents in the US.

Market opportunities were not pursued aggressively. This is one of the key reasons for the slow sales growth of the laser. Conventional lasers were identified as key competitors and comparisons were made on the basis of technical specifications and cost. A variety of communication channels such as press releases, magazine interviews, and newspaper articles were used to broadcast research outomces. For the first buyer, however, well-established relations did play a role. Afterwards, product presentations to potential customers were used to explain product features and applications.

One of the problems in commercialising and managing the innovation was that there was no dedicated team for lasers. The CEO commented that the output would have been more if the team knew that they were just going to work solely on lasers. However, there was no clear vision for PFL-200. Also, there was very limited information about the market and the application areas of PFL-200.

Highlight of the case

The innovation process of PFL-200 was wholly funded through the company's own funds. It had raised large sum of money through venture funding and government grants for the thin-film project, a part of which was used to fund this laser project. Alnair labs Corporation has been getting grants from the Japanese government since the beginning, which helped them cover two-thirds of the R&D expenditure for the basic research projects.

APADENT® and APAGARD® Nanohydroxyapatite Toothpaste

Category:
New Products

KETs involved:
Nanotechnologies

Country:
Japan

Year of market entry:
1980 as cosmetics product, 1995 as quasi-drug product. The toothpaste was completely new to the world. The material is the same as natural teeth, comprising 97% of tooth enamel.

Time from research to market:
Under the 'cosmetics' category - 2 years; under 'quasi-drug category' - 15 years, a series of activities such as clinical trials were conducted during this period.

Availability on the market:
Japan, Russia. The company has sold over 90 million tubes by now.

What made this case interesting for this study:
It was a novel idea to use nano-hydroxyapatite in a toothpaste. At that time, little was known about nanotechnology, the market was hardly familiar with the term and the essence of it. Initially, the product took some time to penetrate the market due to its high price ("the most expensive toothpaste in the world"). Nevertheless, in the later years, due to effective TV marketing campaign, it shot up the sales chart.

Website:
http://www.sangi-co.com/e/products/index.html

Short case description

Nano-hydroxyapatite toothpaste, APADENT® is world's first re-mineralising toothpaste containing nanoparticle hydroxyapatite. It was commercialised by Sangi Co., Ltd., Japan in 1980. Sangi is a pioneer in applications of hydroxyapatite, the biomaterial component of bone and teeth.

At the beginning, the toothpaste was launched under the category of cosmetics - for tooth whitening. However, after rigorous field trials, Sangi's toothpaste material nano-hydroxyapatite got approval from Japanese government to be included into 'quasi-drug' category. From that point, it was known as 'Medical Hydroxyapatite'. Currently, the toothpaste is available in the market mainly under two brand names: APADENT® and APAGARD®.

Innovation cycle

The product is the result of the idea of producing re-mineralising and anti-caries toothpaste using nano-hydroxyapatite.

One of Sangi's early investors had keen interest in a NASA patent on the calcium-phosphate compound. The patent claimed this compound could help in restoring teeth enamel. In 1978, Sangi bought the patent from the U.S. government. To verify the claims for the compound's remineralising effect and for in-vitro testing, several Japanese universities and research centres were mobilised. The findings of this research were central to Sangi's decision to invest in the product. The research was primarily funded by the company's own funds.

The production of the toothpastes has been handled by Nippon Zeola (now Nippon Zettoc) from the very beginning. At the start of the business, the demand was quite low. Production activities were sluggish for some years. In 1990's, due to a huge surge in demand, the production peaked dramatically. The factory staff worked around the clock. In the later course, the demand dropped again. This led to under-used production capacity for some time. Gradually, business improved again. Currently Nippon Zettoc is running at full capacity.

The blocking factors at the initial stage of product development were mainly technical and financial. It was difficult to stabilise the compound and prevent it from hardening in the tube. Later on, marketing played a key role.

Both partner companies were small and able to make decisions and act on them quickly, which was a key factor in the project's success. Much of the success can be attributed to the project leader's personal commitment.

Highlight of the case

Once launched, the toothpaste was extremely expensive, 2,800 yen for 120 grams, roughly ten times the cost of regular toothpaste. Initially, the marketing was targeted at dentists and related actors in the oral care sector. Sales were low.

Later on, a decision was made to take a direct route to drug stores. The toothpaste demonstrations were given at the outlets. Instead of treating cost as a set-back factor, they put the product's high price in the spotlight. Pharmacists were urged to place it on the counter in a special display box and hand-written stickers reading "The most expensive toothpaste in the world" were distributed to the customers. Interestingly, the sales started picking up from here.

NAO robotics research platform

Category:
New Products

KETs involved:
Micro- and nanoelectronics

Country:
France

Year of market entry:
2008

Time from research to market:
2.5 years

Availability on the market:
Academic market

What made this case interesting for this study:
On the one hand, Aldebaran Robotics showcases the rapid progress a highly skilled and highly motivated team can make. This is evidenced by the rather short time to market of the robot. On the other hand, the case is exemplary in how user feedback can elevate the product. Combined with a short-loop process, the implementation of user feedback at an early stage proved to be one of the crucial factors of success in this case.

Website:
http://www.aldebaran-robotics.com

Short case description

NAO is a programmable, 58-cm tall humanoid robot and is used as a research platform by more than 600 prestigious universities and research labs around the world. The robot has human-like features such as arms, a head, and ways to communicate with people through vision and hearing.

Bruno Maisonnier, the founder of Aldebaran Robotics, was strongly convinced that robots can be found everywhere in the very near future. He thought that both the public and the market were ready for robots, but that no such product for them existed yet. This led to the foundation of Aldebaran Robotics in 2005. Nowadays, Aldebaran Robotics employs approximately 230 people, including 130 highly educated engineers and researchers that perform R&D.

Innovation cycle

In 2005, the activities comprised both engineering and building early prototypes, mostly to validate the mechanics and the design. The design was the key issue, as it was a very original approach: they started designing the robot focusing on human users rather than focusing on the design of the limbs and the joints.

In 2007 Aldebaran Robotics had finished the design and were looking for customers. At the same time, they started industrialising the production process.

In 2008, the first generation was produced and sold. It was assembled and distributed by Aldebaran, In the same year, Aldebaran Robotics had developed the industrial process to build the robot.

From there onwards, they actively engaged with the end-users to get feedback. They wanted to stay responsive, so they quickly engineered solutions for the problems users were facing. Moreover, the industrialisation process also brought along feedback on both the process itself and the design, and those issues were also addressed. This was possible thanks to a short-loop process between engineering, manufacturing and user feedback rounds. By doing all that in-house in Paris, they were able to quickly identify problems in both the manufacturing process and from a user perspective.

Following the feedback round, they gradually started outsourcing some of their production starting from 2009. At the moment, NAO is still assembled in Paris, but they are slowly starting to outsource more of NAO's production to cope with the increasing number of sales.

In 2010, they started up a developer program to facilitate a transition to the mainstream market. This program aims to create applications that will allow regular customers to operate the robot.

Highlight of the case

This case of Aldebaran Robotics demonstrated an incredible development of the innovation. During the engineering process, the Robot Soccer World Cup (Robocup) looked for a replacement for Sony's Aibo, the robot dog, which was used for the Standard Platform League (SPL). NAO was selected as the robot for this platform in 2007, which posed a strong deadline for the robot to work.

Even though the people at Aldebaran Robotics started from scratch in 2005, the highly motivated team quickly came up with results and were already selling their first generation in 2008 thanks to the Robocup.

QEF Epilepsy Bracelet

Category:
New Products

KETs involved:
Micro- and nanoelectronics

Country:
The Netherlands

Year of market entry:
2007

Time from research to market:
2 years

Availability on the market:
The BeNeLux

What made this case interesting for this study:
This bracelet may help epilepsy users to live more independently. Moreover, it reduces the workload of the caregivers significantly and it could reduce the costs for caregivers and health insurers. The product is therefore a showcase of high potential and it is interesting to understand the whole innovation process.

Website:
http://www.diepeveenrevalidatie.nl/product/unieke+producten/epilepsie-pols-armband/

Short case description

The "epilepsie polsarmband" is a bracelet that detects epilepsy seizures that involve shaking and alerts caregivers of the seizure. In the Benelux market, where the product is currently being distributed, it is one of a kind and was the first to provide such an advanced solution. The epilepsy bracelet has enormous potential to become a highly successful innovation.

The bracelet helps epilepsy users to live more independently. Moreover, it reduces the workload of the caregivers significantly as it is a very time consuming task to monitor the epilepsy patients all the time. This product could potentially reduce the costs for caregivers and health insurers, and a diffusion to the global market is still an option.

The epilepsy bracelet had several struggles. One of the biggest concerns is the lack of coverage to date by health insurance companies in the Netherlands. This has greatly hampered the diffusion process, but all parties involved with the innovation are convinced that once the product can be covered by health insurance, sales will increase exponentially.

Innovation cycle

Q.E.F. started to work on the epilepsy bracelet from scratch around 2005. Their objective was to determine how to detect an epileptic seizure through a personal device that is easy to carry around during everyday activities. For this they tried out several different technological solutions and established several prototypes that led to a bracelet that is able to detect an epileptic seizure.

In collaboration with their distributor, Q.E.F. improved the prototype to add functionality that allows the epilepsy bracelet to do more than detecting epileptic seizures, such as alerting relevant care providers that the individual wearing the bracelet is experiencing a seizure. Based on the feedback from the end-users, they improved the design.

In order to achieve additional functionalities, Q.E.F. has been in frequent contact with organisations and individuals involved with the end users of the bracelet, such as epilepsy care homes. This allowed Q.E.F. to tailor the bracelet's functionality to the needs of the users, and allowed for testing the bracelet in practice.

The diffusion of the innovation is hampered by the lack of coverage by Dutch health insurers. Insurance coverage of this product is thought to massively increase the demand for the bracelet, which so far has not taken off to the extent that had been expected.

The distribution market was limited to the Benelux, so whether this applies to other countries remains unknown.

Highlight of the case

The epilepsy bracelet can help epilepsy patients to live more independently. It reduces the workload of the caregivers significantly and can reduce the costs for caregivers and health insurers.
However, one of the main obstacles for the massive uptake of the bracelet is the lack of coverage to date by health insurance companies in the Netherlands. All parties involved with the innovation are convinced that once the product can be covered by health insurance, sales will increase exponentially.

QEF currently still has no clear trajectory towards insurance coverage of this innovative and beneficial healthcare solution.

Silverlon® Silver Dressings

Category:
New Products

KETs involved:
Nanotechnology

Country:
United States

Year of market entry:
2001

Time from research to market:
About 15-20 years

Availability on the market:
Silverlon® is sold all over the world to a variety of customers. It has a product range of over 60 different dressings for wound, burn and surgical care and over 5 million products were sold since its start-up in 2001. Their client base includes the US Army and several hospitals in the US.

What made this case interesting for this study:
Silverlon® Silver Dressings provide a sustained release of silver ions directly into the wound, attacking bacteria and fungi that may have been introduced during surgery. The release of silver ions to treat wounds is not new to the market, however the application of the technology is different from that of its competitors

Website:
http://silverlon.com/

Short case description

Silverlon's advanced antimicrobial dressings are made with pure metallic silver, bonded to the surface of the nylon substrate. Silverlon dressings help wounds heal up to 50% faster and Silverlon dressings will not stain wounds. Patients report significant pain reduction and reduced scarring. Health care providers come out on top with fewer dressing changes. Fewer required dressing changes means fewer nursing visits and reduced costs. Clinical evidence has shown this dressing to accelerate healing and reduce infection[105].

Innovation cycle

The innovation cycle associated with the development of Silverlon products includes technology push and was largely financed out of private resources. The silver technology originated from fundamental university research in the 1980s. The original inventor took the fundamental technology of silver coating to nylon to his private practice in order to experiment and develop a final product. The application of the technology through experiments was done in an iterative process in the medical practice of the inventor in the 1990s. Further refinement was done through patient feedback. Legislation at that time was beneficial for experimenting on patients and conducting small in vivo trials. Experimental treatment is ongoing even in the commercialisation phase, throughout the user community.

The original inventor applied for FDA clearance and patents for his first viable dressings in the 1990s. In 2001, Argentum Medical LLC licensed the patents from the original inventor for further development and production purposes. The original inventor did not succeed in commercialisation and therefore licensed its inventions. Argentum was financed through seed capital provided by a group of private investors. Patents were transferred from the inventor to the company in 2008. Argentum started broadening the product range of silver ion based products and additional patents were filed in 2005-2008, leading up to 35 patents today. In the past, Argentum ran into some issues with regard to intellectual property. These issues were mainly dealt with through litigation.

The main success factor in the research phase has been the dedication of one researcher throughout a research trajectory of more than ten years. Moreover the legislation during the development phase of the product was favourable to experimenting with the products. The main success factor behind the commercialization of the

[105] See http://silverlon.com/ where several studies have been cited

Silverlon products has been an aggressive marketing strategy aimed at doctors, hospitals and patients. Also Silverlon was targeted at the US army as a large client for using their products during the Iraq and Afghanistan wars.

The main obstacle in the innovation cycle has been the small financial capacity of the firm obstructing a rapid diffusion in a matured market for medical wound care and bandages.

Highlight of the case

Public procurement by the US military played an essential role in the process of market diffusion for Silverlon products. In the first place it provided Argentum with a large customer base and target market, especially for the burn wound care products which were used in the wars in Iraq and Afghanistan. Secondly, Silverlon was allowed to test products within the army and further develop its product range. Thirdly, it gave the products name recognition which was put to use for marketing purposes in the home care and hospital markets.

T-Sight 5000

Category:
New Products

KETs involved:
Photonics

Country:
Italy

Year of market entry:
2009

Time from research to market:
About 3 years

Availability on the market:
Since its market introduction, Mermec has sold three systems to three different customers in Switzerland, Italy and Czech Republic. At this moment several customers worldwide are considering the purchase of the product. The T-Sight 5000 and its innovative features were awarded with the prestigious Photonics Award in 2011.

What made this case interesting for this study:
The technical origin of the innovation was demand pull. The first client initiated the innovation cycle and requested Mermec to integrate a fast and accurate measurement system that integrated tunnel measurement as well as track clearance gauge, which was never been done before. The combination of the functions benefits clients in terms of maintenance cost, and increased reliability and safety of tracks and tunnels.

Website:
http://www.mermecgroup.com/

Short case description

T-SIGHT 5000 is an advanced and accurate measurement and inspection system dedicated to tunnels and infrastructure clearance. Mounted to the front of a train, the T-SIGHT 5000 system performs an in-depth inspection and analysis of tunnels and clearance profiles on railways, capturing image data of bridges, underpasses, poles, walls, tree branches, and other obstacles that may hinder the safe transport of rail passengers and cargo.

Innovation cycle

The innovation cycle associated with the development of the T-Sight 5000 is customer driven and was largely financed out of private resources. Mermec conducted thorough in-house research. Some components like the lenses and mirrors within the T-sight 5000 have been developed by external suppliers on the basis of the design by Mermec. The T-Sight 5000 consists of several innovative parts rather than one specific innovation.

The outhouse development of components involved transfers of knowledge which were covered by non-disclosure agreements. Some suppliers have been identified through internet research. Market research, the identification of market opportunities and competition analysis were conducted during the research phase. Although the development process was initiated by the Swiss Railway company, Mermec also took customisation options for future clients into account. The research led to the build of several prototypes for the main components. Mermec ensured the functionality of the different components and then produced a final product which has been enhanced through customer feedback.

The challenges that Mermec faced during the development process have been solved through a typical feedback process with suppliers. After design and computer simulation, Mermec built a laboratory prototype to validate the specifications and to adjust the prototype according to the validation. After three years of research and development, Mermec had build a working prototype that met the clients' specifications.

The main success factor behind successful commercialisation of the product lies in the knowledge capital of the company. Mermec has a very experienced R&D team in-house and the company has over 25 years of experience in research and development. Another success factor was strong cooperation between sales and R&D personnel at an early stage of the innovation cycle.

Highlight of the case

The intellectual property for developing the T-Sight 5000 is only protected by non-disclosure agreements between suppliers and Mermec. The innovation is not protected by any patents. In order to obtain a patent Mermec would have to describe in detail what the company has done to develop their product. Mermec is convinced that they are the only company which is able to develop these type of products with these specifications. Therefore the company does not want to disclose information that might be valuable to competitors. Reversed engineering is very difficult because of the very high tech nature of the mirror specifications. The cost associated with copying probably is offset by the potential benefits and hence no further intellectual property protection is required.

Crystalsol: Flexible photovoltaic technology

Category:
New materials

KETs involved:
Nanotechnologies, photonics, advanced materials

Country:
Austria, Estonia

Year of market entry:
The material has yet not entered the market. Currently Crystalsol is producing prototypes.

Time from research to market:
Crystalsol was founded in 2008 and uses the know-how by other associations which started R&D since 1960. EU market access is foreseen by 2015-2016.

Availability on the market:
Prototypes have been sent throughout most of the European countries, particularly in Austria, Estonia, France, Finland, and Portugal.

What made this case interesting for this study:
This photonic nanotechnology is not only interesting for the government but for funding agencies, too, because the demand for renewable energies and green technology is currently very high and still increasing.

Website:
www.crystalsol.com

Short case description

Crystalsol is producing prototypes of an entirely new type of flexible photovoltaic module with a significant cost and versatility advantage compared to all currently known photovoltaic technologies. The core innovations of the flexible photovoltaic module are the crystalline semiconductor powder made from a patented new material and the low-cost roll-to-roll production process.

The flexible photovoltaic module has not entered the market yet but Crystalsol is producing prototypes for companies all over Europe including France, Portugal, Finland and Austria. The development of its new product has benefitted from public funding and support in Austria and in Estonia. Crystalsol expects to start manufacturing by the end of 2014 and to reach the break-even point by the year 2016.

Innovation cycle

Crystalsol's flexible photovoltaic technology is based both on decades of research by the Russian military and on Philips semiconductor know-how. Monograin Membranes are traditionally made of copper indium gallium diselenide (CIGS). The high costs of indium for presented an issue until 2005, when a breakthrough at the Technical University of Tallinn (TUT) allowed the replacement of indium and gallium by zinc and tin.

Crystalsol was founded in 2008 as a spin-off of the TUT with the help of the academic business incubator INiTS. Since then it continued the R&D on the material, in collaboration with TUT. In this way Crystalsol drove the development of the innovative technology. The company started the fundraising process in the first year. Due to the economic downturn, the reduced risk-taking attitude of financers dramatically impaired access to finance of companies in this field. Nevertheless, Crystalsol's management was able to draw funds from several government agencies, which were pursuaded to invest based on the increasing demand for renewable energies and green technology. Still, access to finance remains a critical issue for the company.

In 2010, Crystalsol built its own laboratories to continue its R&D activities. Prototypes of the new technology are being produced and tested at a small scale.

The prototypes have been tested all over Europe, in countries such as Austria, France, Portugal and Finland. Thanks to this initial pre-commercial activity, Crystalsol can now analyse the most suitable markets to access, as well as the related potential market opportunities. After this step, Crystalsol will adapt its business model and fit the product to the market needs.

The commercial scale-up of the material is expected for 2013-2014, and the full production for 2015-2016. Crystalsol expects to reach the breakeven point at the end of 2016.

Highlight of the case

A technological breakthrough significantly reduced the cost for manufacturing a Monograin Membrane. This was considered as the most important constraint to the use of this material. With this barrier reduced, new market opportunities have opened up for the use of this material. Crystalsol successfully used the IP generated by the discovery and further improved on it. A new type of photovoltaic module was developed, combining affordable production cost with the flexibility of the module as an important technical advantage.

Tai Li New Material International: Glow in the dark powder

Category:
New Materials

KETs involved:
Advanced materials

Country:
Taiwan

Year of market entry:
2002

Time from research to market:
1 year

Availability on the market:
Mainly in Asia, but in Europe and U.S.A. as well.

What made this case interesting for this study:
The R&D activities have been distributed between three different places, in two different countries. This is remarkable for a start-up, where the trend is to locate the researchers in only one point, to speed up research activities. Time to market along with worldwide access represents an outstanding example.

Website:
www.talinewmaterial.com

Short case description

Ta Li New Material produces lightening material, a 'glow in the dark powder' based on luminescent pigments which possess a high capacity for absorbing, storing and luminosity. The powder absorbs visible light for 10 to 30 minutes and then lights spontaneously for approximately 12 hours. The powder is used primarily for safety signals, stickers, and wall paintings in public infrastructure.

Ta Li New Material is the only company in Taiwan that produces this powder. Customers are mainly from China and the United States, but the company is also exporting its products to Europe and the Middle East. Market demand has increased over the past few years, and is expected to continue to do so, due to the enforcement of safety regulations requiring the use of luminescent signage and additional product applications, especially in public infrastructure.

Innovation cycle

Ta Li New Material was established in 2001 and the company started the development of its innovative glow in the dark powder with its own capital. The technology was developed in cooperation with non-profit research institutions in Taiwan and there were no joint ventures involved. As a result, the initial R&D costs were acceptable. Ta Li New Material has registered the IP rights in Taiwan.

Ta Li New Material set up R&D teams in Taiwan, Shanghai and Beijing. Industrialisation and manufacturing is done in China, where the raw material used to produce the powder is obtained. A main barrier and challenge for the company was to reduce the hazardous heavy metals from the raw material to use for the powder. When the product entered the market in 2002, acceptance was rather low due to fears that the product might be hazardous.

In the early stage of the innovation, Tai Li Material's R&D teams continued development of the powder by making required adjustments in order to meet the different demands from the customers. This adjustment work was one of the main operational barriers at that time. Ta Li New Material got most of its applications in wall painting materials, although there was also demand for application in stickers and slippers.

Currently, the material is used for applications in safety equipment, toys, ceramic products and building materials. Ta Li New Material does not have a lot of competition in this sector because there are no fully fledged comparable companies on the market yet.

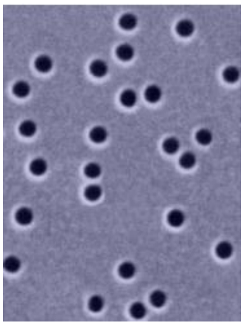
Ta Li New Material is now developing a similar material with a much higher applicability in order to integrate it into a wider range of products. If the development of this new material is successful it will significantly reduce the cost of the product. The company is also looking into producing lightening silk for clothes to better leverage on the R&D portfolio of applications.

Highlight of the case

Ta Li New Material has chosen to distribute its R&D activities on three different locations in two countries (Taiwan, Shanghai and Beijing).

The downside of this choice has turned out to be that the material is not in the cutting-edge side of technology. The R&D activities have been turned towards the functional specifications coming from the market rather than increasing the performance of the material.

it4ip: Track etching technology



Category:
New Materials

KETs involved:
Nanotechnologies, advanced materials

Country:
Belgium

Year of market entry:
2006

Time from research to market:
Approximately one year
However, basic R&D was already undertaken in the 1980s by UCL.

Availability on the market:
Europe, Asia, North America.

What made this case interesting for this study:
Before the patents becoming public, UCL licensed the patents issued for this new material to a former European company, which decided to concentrate its activities in the USA. it4ip created new materials and new properties, and has been able to protect them with new patents.

Website:
www.it4ip.be

Short case description

it4ip designs, manufactures and supplies unique porous templates and membranes and offers related R&D services based on ion track technology of polymers. Track-etching technology is based on the irradiation of polymer materials with energetic heavy ions leading to the formation of linear damaged tracks across the irradiated polymeric layer or film.

The track-etched membranes produced by it4ip are essential for key applications where they are used as a separation barrier, a flow controller, a support component or a screen filter. The membranes are currently used for direct observation and rapid quantification of biological cells or µ-organisms, for cancer diagnosis, for diffusion control in biosensors, for particle capture tests, for rare event recovery and in fuel cells.

Innovation cycle

In its current form it4ip was created in 2006, but R&D on the technology started at the mid of the 1980s as a collaboration between the polymer lab and the cyclotron research center of the Catholic University of Louvain (UCL). R&D on the first prototype of polymer membranes lasted approximately two years and the first prototype of manufacturing machine was functioning and ready to be sold in 1989.

UCL funded therefore a first spin-off company (Cyclopore) at the start of 1990 and industrialisation of the product started in 1991. In 1995, Cyclopore patented its first technological application, and in the same year, Cyclopore was bought by Whatman, a British laboratory equipment maker.

In 2005, Whatman decided to relocate operations from Belgium to the USA. Most of the staff, however, did not follow the company to its new location; with experts from UCL, they established it4ip in January 2006, utilising their contacts and knowledge of the product and of the industry.

The company entered the market quickly after its creation. At the beginning, it4ip provided prototypes, which were tested by the first clients. The customers were well known and a network had already been established. The company started generating profits two years after its creation, thanks to the quick creation of a portfolio of customers.

The company produces specific materials exclusively for single clients to be used in special applications. it4ip attends several exhibitions and trade fairs to present its innovative materials.

it4ip currently sells and distributes its products in India, the Asia-Pacific, the USA, Canada, Europe, South Africa and South America. it4ip continues to conduct R&D to develop prototypes and to offer new services and materials based on this technology. In order to grow further, it4ip is planning to expand the size of its building and increase its production line.

Highlight of the case

it4ip has been created by the former experts and engineers from UCL and from a British company which decided to leave Europe and to concentrate its activities in USA.

Despite the fact that the first patents is now in the public domain, it4ip, thanks to its very high level of expertise, succeeded to develop new materials, to patent them, and to access the global market

Kriya Materials: Functional coating Products

Category:
New materials

KETs involved:
Advanced materials

Country:
Netherlands

Year of market entry:
2007

Time from research to market:
Kriya Materials worked on the R&D for 1-2 years before entering the market in 2007. Basic R&D was already undertaken by Philips since 1990.

Availability on the market:
Europe, USA, Asia (China, Korea, Taiwan, Japan)

What made this case interesting for this study:
The electronics industry is very dynamic und unpredictable. Therefore, advanced materials for this market risk quickly losing their success if a completely new technology enters their market.

Website:
www.kriya-materials.com

Short case description

Kriya Materials is an innovative developer and manufacturer of functional coating products for high-end film and sheet applications. The company's product range is based on doped metaloxide nanoparticles. These particles may have conductive properties, absorb the near infrared part of the solar radiation or the UV part, or have a high refractive index for optical applications. The particles are selectively surface treated in order to provide the optimal fit with the full coating formulation.

The coating formulations can be used in display films, touch panels, 3D applications or window films.

Due to the company's expertise in particle production and modification, the coating products meet the highest standards with respect to optical clarity and uniformity.

Innovation cycle

Nanodispersion technologies were developed by Philips between 1990 and 1995. The technologies were initially used for antireflection and antistatic coatings on cathode ray tubes (CRTs) and they met the highest specifications with respect to particle size, stability and quality of processing. Kriya Materials' core technology is based on the development of such antimony doped tin oxide (ATO) dispersions. This nano metaloxide technology was used for CRT screens made by Philips between 1995 and 2002. In 2002, Philips was restructured as LG-Philips and in 2005 a technical spinout company NanoSpecials was founded. Kriya Materials was established in 2006 and it acquired NanoSpecials in the same year.

Kriya Materials started its own product development in order to broaden the application of this technology. Demand came from large customers in the display film industry, while help and technical support was provided by universities and academia. Kriya Materials continues to fine-tune the technology towards customer specifications.

Kriya Materials' main business is in the electronics sector but it is currently diversifying its product portfolio and has established a presence in other markets. Its main target markets are Asia and the United States.

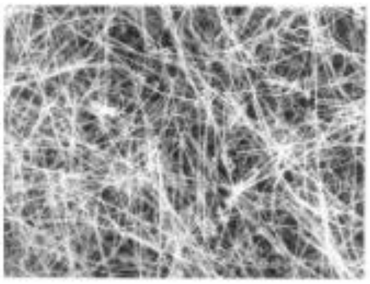
Kriya Materials is continuing its R&D and is developing new prototypes for applications based on functional coating materials. It aims to diversify its portfolio and to be capable of ramping up with commercial production of all developed innovation.

Highlight of the case

Kriya Materials offers a specific innovative technology in the electronics market, which is very dynamic, but which also is unpredictable. The company, aware of the risks related to an instable market, has concentrated its time and effort on the constant development of a wide portfolio of applications of the technology which could quickly access the market.

Kriya combines a top-tier technological skills with a constant R&D commitment. The market knowledge of the top management and its large experience in the field are the main drivers for directing R&D investments towards successful product applications and markets.

Neoker: NKR® single crystal alumina fibers



Category:
New Materials

KETs involved:
Advanced materials, advanced manufacturing

Country:
Spain (Headquarter and R&D); France (Production).

Year of market entry:
2006

Time from research to market:
6 years

Availability on the market:
Spain, France, U.S.A., Japan, Germany.

What made this case interesting for this study:
The very close collaboration between Neoker and a consulting firm specialised in marketing allowed the company to develop a quite distinctive customer segmentation approach. Tackling the right customers is of capital importance especially at the inception phase of the company, when local market adoption has to be gained.
Neoker is undertaking R&D with its highly qualified people that possess a deep technical know-how. Lobbying Consulting is handling the economic, marketing and strategic development of Neoker.

Website:
www.neoker.org

Short case description

Neoker produces and supplies whiskers of pure alumina intended for the manufacturing of MMC's composites (composite metallic matrix), CMC's (composite ceramic matrix), glass and polymers. Neoker is the first and only world producer of whiskers of pure alumina, NKR® single crystal alumina fibres.

The company is developing projects in large industries, including the aerospace, aeronautic, defence, automotive and tooling industries. All of them have shown interest in this kind of material, and for all of them it is as new as it is interesting. The fibres of pure alumina are used in the strengthening at high temperature of ceramic and metallic matrix composites. When included in metallic alloys, these composites increase hardness and resistance allowing use at a very high temperature while offering best value for money.

Innovation cycle

Two researchers from the Institute of Ceramic Materials of Galicia, in association with the Spanish university, worked on the development of nano single-crystal particles of ☐-Al_2O_3. in 2000, Neoker was established by the creators of the technology.

Neoker-France was founded in 2003 in the proximity of Toulouse. Neoker received a seed grant from the Ministry of Industry and Energy for its Neotec programme. Neoker also benefited from the support of two venture capitalists. This allowed the company to develop and to produce advanced materials, manufacturing the composition of alloys in the metal, composite materials, glass and polymers industries.

Neoker entered the market in 2006, made possible by its small R&D projects and trials done with companies operating in defence, aeronautics, aerospace, and automotive markets.

Neoker developed a large capacity oven to produce a greater amount of NKR® fibers, the construction of which took about three years. However, this oven was not designed to ensure continuous production, preventing the company from producing large quantities of material.

A more efficient furnace would allow continuous production and would reduce the production cost of the fibres. Neoker is therefore seeking funding from venture capitalists and industrialists to build it, planning for industrial scale production in 2013.

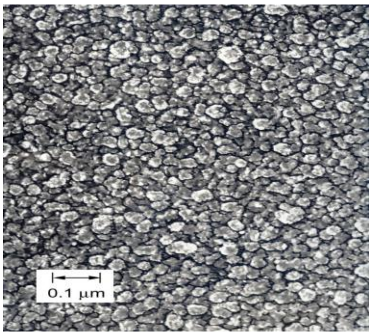
Highlight of the case

Aware of the challenges present at the inception of the market adoption phase, Neoker decided to outsource the development and implementation of its go-to-market strategy. This was achieved by establishing a close collaboration with a third party consulting firm that had the required skills and knowledge that Neoker found itself lacking.

A collaboration was established between Neoker and the consultant firm, in which each partner would contribute to the growth and development of the company by leveraging on their respective core competences.

Neoker is located close to the decision centre and R&D heart of the European aircraft industry. This geographic proximity has allowed for deep relationships with key persons and boosted the value of the business and the company.

Oerlikon Balzers Luxembourg: Diamond coatings



Category:
New Materials

KETs involved:
Advanced materials

Country:
Luxembourg and Switzerland

Year of market entry:
2000

Time from research to market:
6 years

Availability on the market:
EU27, U.S.A., Japan, Brazil

What made this case interesting for this study:
This economic and technical adaption of an extreme material (diamond) to a business area with a medium added value (cutting tools) is an example of technological breakthrough, combined with a smart market access strategy.

Website:
www.oerlikon.com

Short case description

Balzers Luxembourg produces diamond coatings for the engineering industry that are very easy to use. The company produces a chemical vapour deposition (CVD) diamond which can be used on a broad range of applications where current materials have reached their limit. Balzers' ability to make and deposit diamond is a direct result of their proprietary CVD diamond reactor technology, and of their coating services capability. This allows for the deposition of a uniform, thin-film diamond in a cost-effective manner. Uniform and cost-effective diamond coatings have characteristic that broaden the material's appeal throughout multiple industry sectors where diamond could be considered the material of choice.

The easiness of use of the diamond coatings is one of the main drivers of success in the coatings market. The the structure of the substrate remains unchanged, while its increased versatility represents added value for using the material across different industry sectors and applications. This feature is most valued in machineries used in manufacturing processes, where diamond coatings significantly increases the life and performance of tools in highly abrasive machining applications.

Innovation cycle

The R&D activity of the company has been significantly increased in 1994, with the aim of investigating the potential of the material. The key barriers at this level were the pollution of the diamond coatings produced by the metal of the substrate and the difference of physical properties (thermal dilatation) leading to excessive stress.

Once the stage of stabilisation of the diamond coating was reached (i.e. the absence of flaking at the end of the process), the complexities and challenges of scaling up the production were addressed. A new very large production system had been designed and produced. New problems related to the size of this new machine appeared, and had to be solved through further investment and work. A patent on the machine itself was finally obtained. Because of the exceptional hardness of the diamond coatings, Balzers targeted market segments in which cutting tools were integrated within production lines. The first buyers of the diamond coating were small to very small companies, producing standard tools for the electrical discharge machining business. By acquiring diamond coatings, these companies wanted to make a difference, a clear breakthrough vis-à-vis their competitors. To increase the technology behind this material, a competence centre has been created in which key know-how is centralised.

The company is now moving towards the aircraft industry, where the use of carbon and glass fibres induces huge issues on the lifetime of cutting tools and on the quality of final products.

Highlight of the case

The cutting edge technology and unique product features for diamond coating are combined with precise and efficient customer segmentation.

The creation of a competence centre and the concentration of the main resources in one spot helps the company to increase its efficiency, its portfolio of products and its capabilities to give the right response to specific needs of the market.

This efficiency is necessary to sell the material on markets where large margins are not possible. This extreme material can thusly be successful outside niche markets.

Hybrid Plastics: POSS®

Category:
New materials

KETs involved:
Nanotechnologies, advanced materials

Country:
U.S.A.

Year of market entry:
2006

Time from research to market:
Approximately 16 years. R&D already started in 1990 by the current CEO from Hybrid Plastics, Dr. Lichtenhahn.

Availability on the market:
Global

What made this case interesting for this study:

The high performing material initially was developed for very specific needs, originating from a client with top specifications in terms of quality and performance. Hybrid Plastics managed to expand its activities by adapting the material's characteristics to broader application areas.

Website:
www.hybridplastics.com

Short case description

Hybrid Plastics manufactures POSS® Nanostructured Chemicals, Flow Aids, Dispersion Aids and Thermoset resins. POSS® is a Polyhedral Oligomeric Silsesquioxane with a regular, often cubic, inorganic cage structure. The unique properties of this material come from a combination of its rigid structure, its high reactivity thanks to organic compounds, and the fine-tuning of the chemical properties which depend on the organic compounds taking place in the inorganic structure.

POSS® is a stable material which is customer focused, offering exceptional properties even at high temperature and providing solutions for specific issues such as thermal stability, nanoscopic monolayer coverage, and stronger bonding. Moreover, it works in thermoplastics and in thermoset materials. In addition POSS® can be used in a diverse range of application areas, from dental applications to aircraft and automotive industries.

Innovation cycle

R&D on the technology started in 1990 at the Edwards Air Force Base in California, where POSS® was developed. The material was based on the specific needs of the US Air Force and in line with the global research on nano-materials that took place in the nineties. In 1998, Dr. Lichtenhahn and his team created Hybrid Plastics. At the time, the company employed five people that had high technical skills but lacked marketing and sales expertise. Capital was acquired through bank loans and initial investment from the founders themselves.

The company decided in 2004 to move from California to Hattiesburg, Mississippi because of more suitable regulatory conditions and fiscal frameworks. This new location allowed the company to collaborate with the University of Southern Mississippi's School of Polymers and High Performance Materials. The proximity of the school was a deciding factor and it enabled Hybrid Plastics to better understand the chemical and physical mechanisms linked to their products and how to adapt their technologies to different products.

Following the relocation, Hybrid Plastics oversaw substantial improvements in its products and was able to extend the range of applications. To seize new opportunities, Hybrid Plastics expanded its catalogue of products to new chemical compounds, new properties and new applications.

In this phase, Hybrid Plastics obtained several loyal customers including dental, aviation and automotive companies. Hybrid Plastics negotiated with them through supplier specific agreements.

Hybrid Plastics continues to conduct R&D, with an aim to develop prototypes for new applications and to optimise its existing products. Hybrid Plastics has established partnerships with several companies in Europe and Asia to assist in the development of products.

Highlight of the case

The company has succeeded to enlarge its customer portfolio, from a material with very narrowed and specific properties, fine-tuned for aircraft industries, to a very large range of clients including dental companies and companies in the automotive industry.

Hybrid Plastics did not want to focus on only one type of client, very demanding yet with a narrow market, and rather changed its model and its material to other types of clients in larger markets.

Régéfilms regenerated polyethylene granules

Category:
New Materials

KETs involved:
Nanotechnologies, advanced materials

Country:
France

Year of market entry:
2008. The company started generating profits in 2011. Nevertheless, these profits are yet not sufficient to reimburse all prior investment in the company.

Time from research to market:
1 year (basic research not included)

Availability on the market:
France, Austria, Belgium, Germany

What made this case interesting for this study:
advanced processing methods that add value to the material by reducing cost. The price of this material is lower than the current granules produced from the classic chemical industry, with the same quality (e.g., purity and stability).
Company kept the process and technology secret, and did not apply for patents. By introducing the regenerated polyethylene granules on the market, the company became the market leader.

Website:
http://www.regefilms.com/

Short case description

Régéfilms produces regenerated polyethylene granules. This material is made from used polyethylene films, especially from packing bags. The company offers high quality plastics produced from old and used plastic materials.

The demand is high and increasing. Currently, the full capacity of the production plant is already in use. The company plans to open a new production plant in 2014. The demand for this sustainable material is a result of the price of regenerated material being lower than the price of material resulting from the classic petroleum value chain. This material is in full alignment with the strategy of France and the EU concerning trash recycling and sustainable development.

Innovation cycle

In 2007, right before the creation of the company, its leaders undertook R&D on regenerated polyethylene granules. This activity lasted approximately one year. During this period, the market was analysed and a business plan was developed. For the implementation of the business plan, the company received 1 million EUR funding from venture capitalists. An important factor was finding the right location for the company, i.e., close to key sources of raw materials and near the key customers.

In 2008, the first material/product entered the market. The installation of the plant lasted six months and six more months were necessary to further develop the product, set-up the necessary technologies and to do the last tests. In the end of 2008, forty tons of material were produced and sold.

In 2009, the company focused on increasing the quality of the materials and the stability of the process. This activity implies close collaboration with the manufacturers of machines used in the plastics industry. A further investment of 5.5 million EUR was received from the French region Aquitaine, the French agencies ADEM and OSEO, and from banks.

At the end of 2009, the industrial line was defined, stabilised and launched. The period between the first production and industrial production lasted approximately two years. Production increased by a factor of four.

The leaders of the company would like to continue their investments in order to expand the company all over France and to open new production plants in order to be closer to the key suppliers and key customers. Due to the lack of EU regulation on the quality of the used plastic materials and on the use of recycled plastics for products that could be in contact with food, the company is reluctant to open new factories outside its country of origin, despite the large potential.

Highlight of the case

The process and the technology of the innovative materials are kept secret. The company thus did not apply for patents for its process. Its leaders assume that it is not necessary at the moment. This assumption came from a continuous study of their markets, and an early warning system that is used to check if any company is working on similar systems.

In addition, the time period it takes for a patent to be granted makes it in the company's view hardly necessary. Furthermore, a patent alerts competitors of the viability of the material and offers clues about how to create a similar process. Therefore, a patent is not something that the company wants to invest in.

SA Envitech a.s: RECAM®

Category:
New Materials

KETs involved:
Nanotechnologies

Country:
Italy and Czech Republic

Year of market entry:
2009

Time from research to market:
3 years

Availability on the market:
Italy (main market), Spain, Czech Republic, Ukraine and Israel.

What made this case interesting for this study:
SA Envitech is much more focused on R&D than on the strategic development of the company. The majority of the team consists of engineers with a PhD that have deep technical know-how. Developing an entrepreneurial vision is not considered a main priority. This could allow the company to boost development at its inception phase, but might prevent it to better leverage on its cutting edge technology later on.

Website:
www.sa-envitech.com

Short case description

SA Envitech a.s. focuses on research, development and industrialisation of new innovative processes and nanostructured materials for water treatment, contaminated site remediation and wastewater treatment. One of the most successful materials invented by SA Envitech is RECAM®, a new nanostructured carbon material, which has unique reactivity and structural properties.

RECAM® is an unique material which can be easily adapted to specific client needs and which presents excellent nanostructured materials for water treatment without being more expensive than other decontamination products.

Innovation cycle

The inventor of RECAM has been working in the sector of contaminated waste water treatment since 1995, where he quickly noticed a need for new filtering systems. The ones currently used were rapidly out of function, causing important reduction of the production uptime. With this in mind, he began looking for technical solutions and started specific R&D on nano-filtering systems to fulfil the industry's needs. At this time, nanotechnology was considered cutting edge for the wastewater treatment industry.

The start-up Envitech was created in 2007. Originally the company was located in Italy. However, in order to increase funding opportunities, headquarters was moved to the Czech Republic. Envitech received funding from private investors, the contribution of which made out 1/3 of the total funds collected. The company owns all relevant IP, including several international patents that describe the application of its material in water purification and remediation of contaminated sites.

The first industrial plant for wastewater treatment with RECAM® was set up in 2009, with a production of 3 tons per month. The first customer is one of the main players in the field of waste water treatment in Italy and in Western Europe. The industrial production of RECAM® started in 2010 at a pilot level of 3,5 tons per year. In 2011, the production capacity increased to 80 tons per year.

The market dynamics observed in 2009 have been affirmed and even boosted, thanks to new local laws and European regulations on water quality. This has definitely been a key success factor.

Envitech continues its R&D with the Czech technical university of Prague and with its key clients. It is also participating in all necessary certification processes.

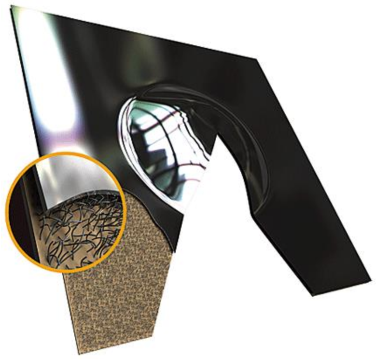
Currently, the company employs 8 people and expects to increase its employee headcount to 13 by 2013. The company owns 6 installation plants and aims to have 15 plants by 2013.

Highlight of the case

The culture of Envitech is driven by cutting edge technology and engineering processes. The passion of the founder towards technical activities is remarkable.
Thanks to the specific needs of the water treatment industry, the strategic positioning Envitech turned out very well; production grew by a factor of 30 between 2009 and 2011.

To further increase turnover and productivity, new investors should invest in the company and introduce a more aggressive marketing and sales strategy.

Lamera AB: Hybrix™ sandwich material



Category:
New materials

KETs involved:
Advanced materials

Country:
Sweden (R&D and commercialisation)
USA (R&D);
UK (R&D);
Germany (R&D).

Year of market entry:
2006

Time from research to market:
2 Years. Lamera undertook R&D in 2004 before entering the market in 2006. However, basic R&D has already been started by Volvo Technologies since 1996.

Availability on the market:
Global, mainly in Europe.

What made this case interesting for this study:
Advanced materials which seem not cost-efficient enough for a specific market can nevertheless present high potential for another market.
This technology comes from the automotive industry and is interesting for the aircraft industry. In this kind of KET, it is generally the opposite (from aircraft to others).

Website:
www.lamera.se/eng

Short case description

Hybrix™ is a very thin, stainless steel micro-sandwich which has been developed by the Swedish company Lamera AB. The unique structure of the individual steel fibres makes the material strong and light, yet very formable. Unlike other conventional lightweight sandwich materials, Hybrix™ can be shaped into compound curves, such as organic forms or the shape of a moulded briefcase. Hybrix™ looks and feels very similar to conventional stainless steel sheet, but it weighs less than half as much.
The technical Hybrix™ sandwich is successful because the material cuts weight by half while maintaining rigidity. Because of the reduced weight, fuel and money can be saved especially in the transport sector. The main application areas are aircraft interiors and portable consumer goods. Other interesting areas range from the automotive industry, architecture, shipping, offshore and medical equipment, to the food processing industry, furniture, and shop displays.

Innovation cycle

The technology was first developed by Volvo in 1996 as a new lightweight material for its vehicles that could save fuel and money. An objective was to reduce the weight of steel by 30-50% to meet future demands of the automotive industry. In 2000, Volvo worked in collaboration with MIT, Cambridge University and with an institution in Germany, to develop the new material and to build the prototype.
In 2004, Volvo realised that the Hybrix™ sandwich material would be too expensive and not cost-effective enough for the automotive industry. Therefore, Volvo decided to stop its research and transferred its patent and technological information to the spin-off company Lamera, which would continue the development of Hybrix™ for industries other than the automotive industry.

The first prototypes of Lamera were developed in 2006. They were suitcases and light equipment to use in aircraft. Later on, Lamera developed a new core material which was much cheaper than the material previously used. Consequently, the company decided to tackle several markets and not to focus only on the aircraft sector. A major success factor of Hybrix™ is that the component can be used in several configurations.

Lamera had contacts in Sweden and all over Europe, even in Asia, to spread its new material. Lamera continuously conducted in-house market research to identify market opportunities. It explored them by participating in trade fairs, meeting aircraft suppliers and carrying out desk research.

Today, Lamera offers a customer-driven strategy without any niche application, adapting the product to the client's needs. For the last 1.5 years, since developing the much cheaper new core material, Lamera has been using this new technology for indoor applications in weight- and cost-sensitive segments.

Highlight of the case

This innovative tough but light-weight material originates in the automotive industry, where it was intended to partly replace the use of steel. Its transfer to the aircraft industry is very likely to be a success, enabled by the robust increase of energy prices. Furthermore, in a couple of years, this material could be used in high-performance cars.

Moreover, Volvo, by transferring its patent to Lamera, made a successful decision in the management of their patents, allowing for an innovative and promising material to be introduced to alternative markets at high future potential.

Green Biologics - Advanced Fermentation Process

Category:
New Production

KETs involved:
Advanced manufacturing

Country:
United Kingdom

Year of market entry:
2012 (Expected)

Time from research to market:
Around five years for the first generation fermentation process

Availability on the market:
The first plant deploying GBL's fermentation process is expected to become operational in China from summer 2012. The company has a few early stage commercial prospects running in India, Brazil and the United States.

What made this case interesting for this study:
New production techniques: GBL has secured several awards in Europe and the U.S., including the Cleantech 100 list for four years running (2008 - 2011), the Clean Connect 30 list (2009), the 30 Most Transformative Technologies of 2010 list, and the coveted New Energy Pioneer Award from Bloomberg News in 2011.

Website:
www.greenbiologics.com

Short case description

Green Biologics Limited (GBL) has developed an advanced fermentation process through its cutting edge research in advanced microbial technology. Currently, GBL has a large library of biocatalysts and has developed a fermentation process that produces low cost and renewable butanol from waste and agricultural by-products. It delivers high performance with strains and sustainable feedstocks at the lowest cost, and with minimum negative environmental and social impact.

GBL provides fermentation technology to customer's facilities in various countries to enable low cost biobutanol production from sustainable feedstocks for the chemical market. Furthermore, GBL's novel process has the potential to reduce cost so that biobutanol can compete in the biofuel market.

The fermentation process by GBL has been recognized worldwide by the sustainable and clean technology industry. It continues to attract investments from diverse clean technology investors. In addition, the company has secured several awards in Europe and the U.S., including the Cleantech 100 list for four years running (2008 - 2011), the Clean Connect 30 list (2009), the 30 Most Transformative Technologies of 2010 list, and the coveted New Energy Pioneer Award from Bloomberg News in 2011 .

Innovation cycle

Fermentation is a biological production process. In simple words, it could be defined as a conversion of sugar feedstock to butanol using microbes. The butanol fermentation is not new. Its development could be traced back to the year 1912, when it was first developed and commercialised in the UK. In 2006, the process was revived in China, when six large scale fermentation plants started to re-commercialise the process. However, the technology adopted by these plants used corn which proved uneconomic.

Cost of feedstock continues to play a crucial role in the trajectory of the fermentation process, as feedstock price accounts for 70% of the overall production cost. GBL's technology, improved microbes for fermentation, allows companies to run their plants on alternative, lower cost feedstocks.

One of the company's strengths lies in its capability to tailor the technology to specific customer requirements regarding feedstock and plant configuration. However, GBL does not fully customise the technology, but instead makes adjustments to suit the customer’s requirements. The company aims to continue technical advancements with time. It has a capability to improve its technical capability quickly after each customer acquisition.

Highlight of the case
The fermentation process by GBL has been recognized worldwide by the sustainable and clean technology field. It continues to attract investments from diverse clean technology investors.

In addition, the company has secured several awards in Europe and the U.S., including the Cleantech 100 list for four years running (2008 - 2011), the Clean Connect 30 list (2009), the 30 Most Transformative Technologies of 2010 list, and the coveted New Energy Pioneer Award from Bloomberg News in 2011.

Local Motors

Category:
New Production

KETs involved:
Advanced manufacturing

Country:
United States

Year of market entry:
March 2008, public launch of the Forge website; November 3rd 2009, Rally Fighter prototype premiers at SEMA; July 4th 2010, first micro-factory in Phoenix, Arizona; August 2010, production of the first Rally fighter.

Time from research to market:
3 years (2007 – 2010)

Availability on the market:
Global market. Ideally customers would live in a 3-hour radius from a micro-factory for overnight maintenance. Nonetheless, Rally Fighters can be ordered all over the world.

What made this case interesting for this study:

Local Motors has developed an online platform for crowd source co-created vehicle design. The platform has attracted a multi-disciplinary online community with over 30.000 members and various backgrounds in designing, engineering and production. The platform seems to be both technically capable to produce vehicles and profitable to reach its break-even point.

Website:
http://www.localmotors.com/

Short case description

Local Motors (LM) is a new breed of car developer/manufacturer producing small quantities of vehicles for niche markets. The designs are developed through crowd sourcing and co-creation initiatives, and the cars are assembled in local micro-factories. In addition, LM offers future owners an automotive experience through involvement during a large part of the 14-day building process.

Innovation cycle

It is important to note that a distinction is made between the process and product. The process involves the crowd source and co-creation platform of local-motors.com called "The Forge", where designers, engineers and producers can meet. The Local Motors product that comes from that process is the Rally Fighter, a 50-state street legal desert race car that was designed and developed by an online community. The engineers at LM further refined the design before the car went to production.

The process innovation cycle started with the idea generation phase. The founders had a passion for cars, recognised an opportunity within the automotive industry, and developed the innovative concept. The technical idea would target this opportunity and thus can be considered as market pull. In the subsequent phase the founders developed a preliminary design for the process and attracted funding.

For the idea to grow from a concept into a preliminary design, LM needed additional funding besides the money it won from competitions. In 2010, 45 angel investors financially supported LM with a total sum of $4 million. Another early step that has been taken to successfully commercialise was the launch of the website named "The Forge". This website enabled real-time communication between LM and its community of designers. As the community started to grow, people ceased to question the legitimacy of LM and attracting more members became much more manageable.

In the third phase of the process innovation cycle a detailed design was created. When the prototype was well received at the SEMA show, a micro-factory opened in Phoenix, Arizona and the firm was ready to start production.

The final phase of the cycle was implementation, which started when LM began production in their first micro-factory in Phoenix Arizona.

During the cycle the founders of LM encountered into two main barriers; the natural hurdles of a start-up, and the lack of government subsidy. These two, combined with an economic recession, made finding start-up capital funding for a manufacturing company and project funding difficult to obtain.

Highlight of the case

The Local Motors case is an example of a crowd-source based production and innovation. Crowd sourcing is a process that involves outsourcing tasks to a distributed group of people, in this case an online community of automotive designers, engineers, fabricators and enthusiasts.
For this model to work, the community needed to be large enough to ensure it would be multi-disciplinary and could generate the required richness of the designs.
To this end, LM targeted 80% of the graduates from top automotive design programs who did not find employment with major car manufacturers.

MakerBot 3D printer crowdsourced manufacturing

Category:
New Production

KETs involved:
Micro- and nanoelectronics; advanced manufacturing

Country:
United States

Year of market entry:
First sales of printers: April 2009; crowdsourced manufacturing: August 2009

Time from research to market:
3 months (basic research not included)

Availability on the market:
global market (more than 10,000 units sold so far in North America, Europe, Australia, New Zealand, Argentina etc.)

What made this case interesting for this study:
new ways of organising production: MakerBot claims to be the first company to ever do crowdsourced manufacturing, i.e., the company involved its own customers in producing parts for new products (3d printers bought by customers were used for producing components for new 3d printers, and customers played a role of business partners).

Website:
http://www.makerbot.com

Short case description

MakerBot Industries is a New York-based company founded in January 2009. The company is producing open source hardware, specifically 3D printers. MakerBot builds on the early progress of the RepRap Project. MakerBot's goal is to bring desktop 3D printing into home at an affordable price.

MakerBot was unable to keep up with the demand for their 3D printer, so they have turned to their customer base and asked them to manufacture some of the parts (pulleys) for them using the existing 3D printers. The owners of the 3D printers were thus helping MakerBot with producing new 3D printers.

However, the approach of having customers print pulleys for MakerBots was successful only for that particular period of time. Later on, the company discovered a cheaper way of producing pulleys internally again.

The concept of crowdsourced manufacturing generally implies that instead of having a centralised factory that produces parts and then distributes them to the people who want them, individuals have the tools they need to build what they want and distribute it without a central hub. In the case of MakerBot, manufacturing was distributed, but distribution still used the hub model.

Innovation cycle

The innovation cycle consisted of four main activities.

Activity 1: Initial system design and synthesis

The introduction of the idea was driven by an urgent need of solving a technical issue with laser-cut pulleys. One of the possible solutions was to print out those pulleys on existing MakerBots. That required adjustments in the existing printer manufacturing process.

Activity 2: Modeling, analysis and simulation

The MakerBot team had to take care of the necessary internal procedures to ensure smooth integration of user-manufactured pulleys into their production process. Such procedures included labour requirements, planning, evaluation of a change in product volume, production scheduling, and quality control.

Activity 3: Final design and implementation

The first boxes with pulleys arrived in 2-3 weeks. The exercise was successful for 4-5 months and 'saved' the company.

Activity 4: Redesign and reconfiguration

Later on, the company switched to a cheaper way of producing the pulleys internally.

Highlight of the case

It took the MakerBot team about two hours to put the idea on the blog. Additionally, they also addressed their customers by email. The first two hours before the announcement was posted on the blog were devoted to developing a design for a printable version of the pulley.
The company offered to pay 1.00 USD per pulley for 608 idler pulleys. When having at least 30, one needed to mail them to MakerBot.
The current innovation did not require any special funding. It implied developing a user-friendly downloadable design of the pulley, posting an announcement on the blog and then performing the quality check of received pulleys.

Nulife Glass

Category:
New production

KETs involved:
Advanced manufacturing

Country
United Kingdom

Year of market entry:
2011

Time from research to market:
The founder/inventor Simon Greer started developing the idea after he perceived the need for a recycling process that could separate the two components of leaded glass 18 years ago. There have been many obstacles during the development and process of commercialisation.

Availability on the market:
UK. Sweeep Kuusakoski is the first customer currently implementing the process. Nulife Glass itself has started to deploy the technology on their own sites in the UK and USA.

What made this case interesting for this study:
This technology is new to the world in its current form. It is the world's first industrial furnace capable of recovering pure glass and lead from glass cathode ray tubes (CRT) used in television and PC screens, in a environmentally sustainable manner.

Website:
http://www.nulifeglass.com/

Short case description

Nulife Glass is the first company in the world to have developed a genuinely sustainable solution for cathode ray tubes (CRT) recycling. The innovative CRT recycling process can extract lead from up to 10 tonnes of funnel glass per day. The process has no significant emissions, creates no waste and avoids export of hazardous materials from the country where it entered the waste stream.

Innovation cycle

Eighteen years ago, the founder of the company perceived the need for a process that could separate the two core elements of CRT screens, lead and glass. The innovation cycle is customer driven. Key phases in the cycle were successful networking with people in different industries, use of experimental setups to gain insight into the core solution for the problem, the start-up of a company to further pursue the perceived business opportunity, the construction of test furnaces, construction of a pre-production furnace, construction of a full scale industrial showcase furnace and commercialisation, and finally the start-up of a fully operational facility.

In the first two phases the background of the founder in recycling, as well as exploring solutions with people in different industries, were important success factors. After perceiving a potential business opportunity for the CRT recycling solution, the founder moved the intellectual property into the newly founded company, Nulife Glass ltd., to pursue further developments. Subsequently the founder developed test facilities, a pre-production furnace, and a full scale industrial furnace as a showcase to prove that the technology works.

Throughout the cycle attempts were made to acquire funding from banks and national and European government agencies, which nearly all failed. Besides one government backed loan from a bank and a small subsidy from local government, no external funding was acquired. The whole process has been funded by the savings of the founder and his family.

The development of this process has been a success due to a highly motivated founder and team members. A multidisciplinary team facilitated original, creative thinking in relation to technology development.

On a macro level the worldwide decreasing sales of CRT TVs, means that more and more leaded glass is ending up at landfills. Closed-loop recycling is no longer a possibility and demand for a more sustainable solution is increasing.

The largest barriers in the development process have been The delayed UK introduction of the EU WEEE directive, resource scarcity, especially in terms of financial support, and the required secrecy of the newly developed technology, needed because the company did not have the resources to defend a patent.

Highlight of the case

Due to the rise of LED/flat screen technology, the production of CRT screens is diminishing. This implies that the window of opportunity for this technology is closing.

Nulife Glass therefore decided to start operating the process at their own sites throughout the UK, as this would significantly reduce the time needed for implementation. This meant no delays due to pending orders, and no real familiarising time needed for operating the technology.

Rhodia, innovative process for the recycling of rare earth

Category:
New Production

KETs involved:
Advanced manufacturing

Country:
France

Year of market entry:
First quarter of 2012

Time from research to market:
Approximately five years.

Availability on the market:
The process has been implemented at two of the Group's plants in France (Saint-Fons and La Rochelle)

What made this case interesting for this study:
New ways of organising production: Rhodia has developed a process that generates rare earth from used light bulbs, cooperating with ecological organisations in an urban mining process to obtain this raw material. The process that Rhodia developed enables the recovery of about 95% of the rare earth materials found in the luminescent powders, which would otherwise end up in landfill.

Website:
http://www.rhodia.com

Short case description

Rhodia, the world leader in rare earth-based formulations, has developed a new process for the recovery and separation of rare earths contained in used low-energy light bulbs. This process for the recycling of luminescent powders opens up new environmental and economic prospects at a pan-European level.

The new recycling process at Rhodia is a multistage process, which combines hydrometallurgy with pyrometallurgy and liquid separation. This process allows for the recovery of all different types of rare earth materials contained in compact fluorescent lamps (CFLs). Generally, six different rare earth materials are used in florescent lamps. Currently, Rhodia is the only company in the world that possesses a process which, on an industrial scale, is able to recycle all of these different types of material.

The current facilities at La Rochelle and Saint-Fons are demonstration units. In the near future, they will be further developed into full scale, fault free, industrial units.

Innovation cycle

The development process for this innovation was started in 2007. After the development process was completed, the company decided to invest in the implementation of the technology on an industrial scale in July 2011. The company decided to start the implementation process in March 2012. The whole development process took roughly five years.

The development process of this innovation has followed Rhodia's standard R&D procedure. This standard procedure consists of five different phases of development.

The process started in the laboratory, where the different possible ideas and solutions were tested. After initial testing and comparisons, a development roadmap was created that further determined the pursued development trajectory.

After this was done, the legal department checked the freedom to operate and patentability of the technology. The initial patent that was applied for turned out to be unsuitable for the protection of the process, therefore the company applied for a second patent.

After the patents applications were filed, the company decided that it wanted to commercialise the technology in collaboration with a partner. After one year of partnership, Rhodia decided to continue on its own.

When all aforementioned steps were completed to a satisfactory level, the project was moved from the laboratory to an industrial scale setting. During implementation, continuous development will remain key, in order to improve the process.

Highlight of the case

The process that Rhodia developed enables the recovery of about 95% of the rare earth materials found in the luminescent powders, which would otherwise end up in landfills.

Moreover, following its standard R&D procedure, Rhodia has managed to develop this process within five years, beating by three years the industry standard research to market trajectory for this type of innovation, which normally requires eight years of continuous development effort.

DyeCoo's liquid CO2 textile dying process

Category:
New Production

KETs involved:
Advanced manufacturing

Country:
The Netherlands

Year of market entry:
The official product launch was in 2010, but the first machine was implemented at the site of a partner in 2011.

Time from research to market:
4 years (not including development of initial prototype at FeyeCon; this took another 7 years)

Availability on the market:
Global market

What made this case interesting for this study:
DyeCoo Textile Systems B.V.claims to be the world's first supplier of industrial CO2 textile dyeing equipment. Furthermore, strategic partnerships were established to create demand pull in an attempt to boost the diffusion of the innovation.

Website:
http://www.dyecoo.com

Short case description

DyeCoo Textile Systems B.V. is the world's first supplier of industrial CO2 textile dyeing equipment. By replacing water with pressurised CO2, the process of dyeing textiles becomes more economical and more environmentally friendly. Other advantages include the elimination of wastewater discharges, a reduction in energy consumption, a reduction in air emissions, and a reduction in dyeing time.

The company was founded in 2008 as a spinoff of FeyeCon. FeyeCon is a company that specialises in developing innovative new processes and products based on pressurised carbon dioxide technology.

Innovation cycle

Before DyeCoo Textile Systems B.V. was founded, an initial prototype of the machine was developed at a different company, called FeyeCon. This started in 1998 and took about seven years to complete. It was only in 2007 when the founder of DyeCoo Textile Systems B.V. came in contact with FeyeCon's owner. They decided to cooperatively search for funding in order to commercialise the liquid CO2 textile dyeing technology. Once the required funding was found among private investors and the Dutch government, they founded DyeCoo in 2008.

The initial prototype formed the basis for DyeCoo's current technology. The company entered a phase of idea generation and conceptual machine design. The key focus was to scale up the process to a full working industrial machine. This was mostly done through trial and error. At this stage, an optimal design was developed, which determined what the final machine should look like.

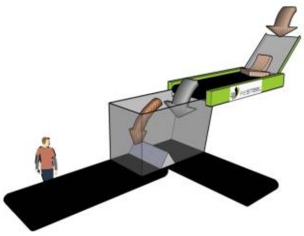
After the conceptual machine design was completed, it was broken down into its most key components. DyeCoo then sought for adequate suppliers to develop these parts. Clear 3D drawings of the conceptual design, performance measures, and other parameters made sure that these suppliers knew what to develop. The suppliers then drew up the designs of the separate machine parts, which were integrated in the overall design of the machine.

Once all components were designed and manufactured, DyeCoo started assembling the machine. The machine was then run for 10-11 months, to check whether it functioned properly. After these tests had been completed, the facility was shipped to their first customer, where additional modifications were made. Further reconfiguration to make the machine completely error free will take place over the coming years.

Highlight of the case

In order to boost the diffusion of the innovation, DyeCoo aimed to set up strategic partnerships with large fashion brands to create demand pull. As a result, they successfully partnered with Nike, a leading sports fashion brand. Nike believes DyeCoo's technology to be promising and therefore aims to support the diffusion of this process.

ReSteel



Category:
New Production

KETs involved:
Advanced manufacturing

Country:
The Netherlands

Year of market entry:
2009

Time from research to market:
2 years

Availability on the market:
Global market

What made this case interesting for this study:
The early involvement of a Venture Capitalist made it possible to bring disruptive innovation to the market. Recession in targeted market made it very challenging for the company to build up positioning. Successful turnaround resulted from highly collaborative partnership between the investor, University and management.

Website:
http://www.resteel.nl

Short case description

ReSteel B.V. is a spin-out company from the Technical University of Delft (TU/d). The company was founded in 2008 as a partnership between TU/d (30% share) and IcosCapital (70% share), a venture capitalist focused on providing seed capital.

ReSteel's Clean Scrap Machine extracts non-contaminated Ferro parts from a mix stream ofscrap. This ensures that scrap continues to serve as a vital source of raw materials for both the steel and copper production industries.

If Icos Capital had not invested, this innovation might have stayed at TU Delft with only a couple of commercial implementations of technology. Technology companies are generally conservative about introducing disruptive innovations. They would much rather buy technology after it is proven on industrial scale and has strong commercial traction already. TU Delft needed capital, market network and expertise on how a start-up (mouse) can take on major market (elephant) size market opportunity without waking up the large (gorilla) size competitor. This is where the partnership between Icos Capital and TU Delft as center of innovation works well.

Innovation cycle

The initial research phase started in 2007, After a professor at TU/d had learned about the possible demand for this kind of process. In this phase, they developed the technology behind the innovative recycling process.

Upon founding, Resteel went into a conservative market of waste and recycling with disruptive technology and a team that did not come from the industry but had strong start-up / entrepreneur experience. The company in the beginning did very well because they had an early sale but at a point in time, market soured, recession happened, steel prices went down and recycling companies decided not to invest in innovations. Also recycling companies demanded a more complete solution.

With current team out of ideas, shareholders sought expertise of its board of industry advisors and also brought on board strong industry expert – as manager- with more in-depth experience in the waste / recycling sector. Shareholders, advisors and new manager together engaged into a turnaround process with input from customers. This understanding, coupled with a more focused marketing approach, successfully turned ReSteel around and lead to new sales.Resteel is typical of a seed / early stage start-up from a university that needed to drastically alter its strategy and team to build strong company. Looking back at the history of the company; a few but very important variables need constant tweaking when introducing a new product in the market, i.e.; (a) business model; (b) market positioning of tech / product; (c) completion of product in response to market expectations; and (d) team. This demands hand on mentality and close collaboration between investor, inventor and management.

Highlight of the case

The early involvement of the venturecapitalist provided the necessary funding, team and expertise to build a business.

Recessionary market and early nature of the business in terms of unproven business model and new technology made it very difficult for company to succeed.

TU Delft and Icos Capital and board of industry advisors worked closely to bring in industry team, additional investment and engaged into a committed turnaround process with success.

Ricoh’s cart production line

Category:
New Production

KETs involved:
Advanced manufacturing

Country:
Japan

Year of market entry:
2005

Time from research to market:
3 months to get from initial concept to final design, 3 months to get from final design to implementation.

Availability on the market:
Ricoh is a global company, hence the innovative production process touches the global market

What made this case interesting for this study:
New ways of organising production: Replacing conveyor belts with flexible cart lines has resulted in significant efficiency gaines and opened up novel sales avenues for Ricoh.

Website:
http://www.ricoh.com

Short case description

Ricoh is a production company specialized in printers, scanners, and photocopy machines. It has replaced fixed conveyor belts with push carts that allow for a flexible in-cell production process, massively increasing production efficiency.

Conventionally, a conveyor belt would transport a product across different stages of assembly, with workers placed along-side the conveyor belt, repeating their task within the assembly process for every unit passing their work station.

Ricoh’s plants in Japan have deployed air pressure-propelled robotic carts to transport units through the manufacturing process, replacing the conveyor belt system, which resulted in a drop of power consumption and carbon dioxide emissions by 99%, and allows the possibility of the assembly process to be powered solely by a photovoltaics.

Because the layout can be freely changed, the formation can be rearranged on a case-by-case basis to suit equipment models and production volumes. Ricoh managed to reduce in-process inventory, lead time, space, and maintenance by 80%. The cart line is now used as a model for introducing the layout-free production system in production sites around the world.

Innovation cycle

The innovation cycle consisted of four main activities.

Activity 1: Initial system design and synthesis

The engineers at Ricoh designed the process in three months, firmly focusing on the functional requirements of the process and of the carts. The engineers could draw upon existing academic work on cell production and the transition from line to cell production.

Activity 2: Modeling, analysis and simulation

Ricoh’s engineers verified the technology by prototyping a cart line and testing it in a controlled setting. Important result of the tests was that the motion control of the carts was in need of improvement.

Activity 3: Final design and implementation

The engineers at Ricoh finalised the design based on the test results and the finalised functional requirements, and implemented the cart line on an industrial scale.

Activity 4: Redesign and reconfiguration

The engineers at Ricoh revisited its design in 2007 and again in 2009 to decrease the physical effort required of workers when assembling units alongside the cart line.

Highlight of the case

Replacing conveyor belts with flexible lines of air pressure-propelled robotic carts has resulted in a drop of power consumption and carbon dioxide by 99% and allows the possibility of the assembly process to be powered solely by photovoltaics. Also, the cart lines reduce in-process inventory, lead time, space, and maintenance by 80%.
These efficiency increases have been reason for Ricoh to implement the cart lines in six of their manufacturing plants.
Four other major Japanese manufacturing companies have cooperated with Ricoh's engineers to introduce this innovative concept to their own plants.

Liquisort – Magnetic Density Separation (MDS)

Category:
New Production

KETs involved:
Advanced manufacturing

Country:
The Netherlands

Year of market entry:
2011

Time from research to market:
5 years

Availability on the market:
Global market

What made this case interesting for this study:
The magnetic separation system being used, which got granted a patent, is new to the world. While a magnetic density separation technique in general has already existed for almost fifty years, successful industrial scale up had never been achieved before. Numerous collaborations, both between industry players and between industry and a university, played a key role in the development and commercialisation of the technology.

Website:
http://www.liquisort.com

Short case description

Liquisort Holding BVBA is the very first company to commercialise magnetic density separation technology. The basic principle on which the technology is based has already been on the market for over 40 years. The first ideas originate from around 1972. With those ideas and prototypes, however, it was not possible to sort large quantities of materials, but only a few kilos per hour. The current Liquisort setup can easily process 6,000 kilos per hour.

The key benefit of this process innovation is that, opposed to its competitors, Liquisort can separate waste input based on its specific material density. Competitors are still using 0ptical separation techniques based on for instance colours or particle size, factors that are not directly related to the material's properties.

Innovation cycle

In 2006, the company Bakker Magnetics developed the idea to create a new sorting facility for waste material. The technical origin of this idea stemmed from the Delft University of Technology, which, based on some old patents, developed the first elementary idea for this innovation. Through a partnership, the university conducted experiments on behalf of Bakker Magnetics, which provided the university with the required equipment.

Liquisort Holding BVBA, in collaboration with an external design firm and many of its largest suppliers, developed the idea into an industrial scale facility in 2008. At this point in time, the company decided to partner with a player from the recycling industry, to attract some practical knowledge in operating a recycling facility.

In 2009, Liquisort Holding created a joint venture with the recycling firm Overdie, to further pursue commercialisation of the technology. The newly founded company was called Liquisort Metals B.V.

The development trajectory has been ongoing for 6 years now. In the beginning the progress was very sluggish. First the business potential of the technology needed to be explored. The first year was mainly spent on exploring possibilities and development of the magnet system. After this stage was completed, focus was put on developing the patent for the magnetic system and construction of the sorting equipment.

Currently, the final design of the installation is finished and focus during the last year has mainly been on finding customers and partners.

Highlight of the case

One of the most important success factors for both the development and commercialisation of this technology, comprises the numerous collaborations between key industry players.
For the development, Liquisort Holding BVBA closely collaborated with suppliers of machine parts and the process liquid. In return for preferential supplier contracts, suppliers like the VDL Group were willing to facilitate testing of machine parts at their sites.
Furthermore, joint ventures with two established players in the recycling market, Overdie and AKG Polymers, were crucial for the commercialisation and final design of the process.

Ponoko – the world's easiest making system

Category:
New Production

KETs involved:
Advanced manufacturing

Country:
New Zealand

Year of market entry:
2007, launch at Tech Crunch 40 in San Francisco, CA

Time from research to market:
9 months

Availability on the market:
global market (production hubs have been established in New Zealand, the United States and throughout Europe)

What made this case interesting for this study:
New ways of organising production: the Ponoko production system includes 'production hubs' on different continents, that employ innovative fabrication methods such as 3D-printing, laser cutting, and CNC routing.
Extensive user involvement: Ponoko has involved users in its development as early as possible to benefit from their feedback, and continues to rely heavily on the feedback of its global online user community to improve upon the concept and the way it is understood and interacted with.

Website:
http://www.ponoko.com

Short case description

Ponoko is an online marketplace for everyone to click to make real things. It is where creators, digital fabricators, materials suppliers and buyers meet to make (almost) anything, based on digital design software and innovative fabrication methods such as 3D-printing, laser cutting, and CNC routing.

This is especially attractive for people that for instance want to have a prototype built, and for small business owners that are in the market for the manufacturing of small volumes of sellable objects. Governmental research labs also use the production serviced through Ponoko. Some fabricators now produce several thousand objects per month, selling them through different channels.

Ponoko's development took place over a limited period of time. Of major importance in the development of Ponoko was their interaction with users, to analyse how individuals would interact with the system, and to gain their feedback and practical insights on how the Ponoko system was developing.

Innovation cycle

The innovation cycle consisted of four main activities.

Activity 1: Initial system design and synthesis

Most of the technology required for the Ponoko system was already in existence. Only the design language had to be specifically developed. However, Ponoko did combine existing technology in a manner that was new to the world.

Activity 2: Modeling, analysis and simulation

Analysis and simulation of the concept took place early in the development, by involving potential users and customers to analyse how these individuals would interact with the Ponoko system, and to gain their early feedback and practical insights on the Ponoko system.

Activity 3: Final design and implementation

The final design before the system was considered market-ready came nine months after the start of the development and two months after the Ponoko system was officially launched at Tech Crunch 40 in San Francisco, CA. A lot about that release would be revisited more than once.

Activity 4: Redesign and reconfiguration

A fundamental redesign has not taken place. Reconfigurations take place continuously, as the design language software needs be updated and improved constantly, based on the feedback the Ponoko company receives from its user community.

Highlight of the case

A big hurdle that Ponoko had to overcome is that, at first, nobody understood the concept. The market in which the Ponoko company operates is similar to the 1978 computer market, where sellers need to invest in up-skilling potential buyers.

The Ponoko concept incorporates a tool that requires a specific level of skill for people to engage it. It doesn't naturally occur to people and it requires a new type of thinking. Users need invest time and energy before they can benefit from Ponoko.

The company offers online community managers that help users understand Ponoko and how to benefit from it, through online channels such as blogs, forums, social media, YouTube, and webinars

European Commission

Innovation - How to convert research into commercial success story?

Part 3 : Analysis of innovation successes in the field of industrial technologies

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The three publications «How to convert research into commercial success story?» aim to analyse how to successfully bridge the gap between research outputs and innovations' access to the market in the area of industrial and enabling technologies.

Three complementary approaches were followed:
This report provides an analysis of commercial successes not necessarily funded by the European Union in the field of industrial technologies.

The report «How to convert research into commercial success stories? Analysis of EU-funded research projects in the field of industrial technologies» retraces the pathways from research outcomes to commercialisation.

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