European Commission

Study on skills related to Key Enabling Technologies (KETs)

Final report

Written by Dr. Kristina Dervojeda and Jan-Hendrik Schretlen
August – 2015

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Research and Innovation

EUROPEAN COMMISSION

Directorate-General for Research and Innovation
Directorate D— Key Enabling Technologies
Unit D1— Strategy

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PricewaterhouseCoopers

Directorate-General for Research and Innovation
2015 Key Enabling Technologies EN

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Luxembourg: Publications Office of the European Union, 2015.

PDF ISBN 978-92-79-52300-7 doi: 10.2777/83363

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ABSTRACT

This report represents the Final Technical Report for the "Study on skills related to KETs". The report has been prepared by PwC EU Services. The general objective of the study is to provide the Commission with the analysis and recommendations on skills in the NMBP areas, aiming to tackle the growing skills imbalances, both from the Horizon 2020 and from policy perspectives. Specifically, the study aimed to develop recommendations on how Horizon 2020 can help tackle the issue of skills imbalances in the NMBP areas. Another intention is to expand the variety of project beneficiaries and include new groups of stakeholders.

Also, the study includes recommendations for other relevant Research & Innovation policy measures to tackle the skills imbalances in KETs. The recommendations have the form of guidelines listing the main issues and most significant measures to be included in the Horizon 2020 Work Programme 2016-2017 and topic descriptions. The recommendations are structured along the four thematic areas of technical skills, mobility, entrepreneurial skills, and HR management skills. The results of the study are primarily to be used for fostering skill-related activities in research-based projects, while also considering an opportunity to embed the skills aspects into the monitoring activities of such projects.

EXECUTIVE SUMMARY

This report represents the Final Technical Report for the "Study on skills related to KETs" (contract notice 2012/S 144-240132; RTD-NMP1-2013-Skills). The report has been prepared by PwC EU Services (hereafter "PwC") for the Directorate-General for Research and Innovation (hereafter "DG RTD") of the European Commission (hereafter "the Commission").

The general objective of the study is to provide the Commission with the analysis and recommendations on skills in the NMBP areas, aiming to tackle the growing skills imbalances, both from the Horizon 2020 and from policy perspectives. Specifically, the study aimed to develop recommendations on how Horizon 2020 can help tackle the issue of skills imbalances in the NMBP areas. The recommendations were developed in a form of guidelines listing the main issues and most significant measures to be included in the Horizon 2020 Work Programme 2016-2017 and topic descriptions.

The results of the study aim to be primarily used for fostering skill-related activities in research-based projects, while also considering an opportunity to embed the skills aspects into the monitoring activities of such projects. Another intention is to expand the variety of project beneficiaries and include other relevant groups of stakeholders, not previously included.

In addition, the study aimed to develop recommendations for other relevant measures at the level of Research & Innovation policy that could help tackle the skills imbalances in KETs. The outputs provided in this report refer to suggestions for other actions, including further studies, as well as other policy measures. We focus on policy measures where European dimension is particularly important; however, we also address the role of stakeholders at other levels, including national and regional policy levels, as well as educators, and industry, particularly SMEs.

The study aims to address the issue of skills in the NMBP areas within the following four thematic areas: (1) Technical skills; (2) Mobility; (3) Entrepreneurial skills; and (4) HR management skills. In order to increase the effectiveness of the study, we aimed to maximise the use of other relevant on-going KETs initiatives, as well as activities related to tackling skills mismatches in Europe. The analysis within the four thematic areas was based on desk-research combined with in-depth interviews with the relevant stakeholder groups including both academia and industry, and particularly SMEs, as well as supporting structures and other relevant organisations.

Below we highlight the key aspects of each of the chapters.

Methodological aspects (Chapter 1)

Throughout the project, several key methodological observations were made. Due to a highly specific nature of research questions of this study, the available desk-research sources on these issues proved to be highly scarce. We were able to use the literature mainly for sketching a general context for the research questions, rather than for finding direct answers.

In order to maximise the effectiveness of our interview invitations, we approached the potential informants at the very early stage of the study, by clearly explaining the nature and background of the study, and the expected inputs from their side. Furthermore, we guaranteed impartiality in the analysis, as well as anonymity and security of data.

For HR management practices, we developed case studies based on organisation; we indicate the type of organisation, its size and the relevant KET(s) it works in, in order to specify the relevant context.

In the course of our analysis, we were able to identify a wide variety of different other policy measures that would help tackling KETs skills-related issues. Some of them are of broader orientation, while others exclusively focus on KETs, and particularly NMBP. Not all of the identified measures were of equal importance to our analysis.

Key findings (Chapter 2)

In the following paragraphs we outline the key conclusions of our analysis within Thematic area 1 (Technical skills), Thematic area 2 (Mobility), Thematic area 3 (Entrepreneurial skills) and Thematic area 4 (HR management skills).

The key conclusions of our analysis within ***Thematic area 1 (Technical skills)*** are as follows:

Relevant technical skills for KETs can be split into several sub-categories related to scientific/technical background, design, ICT skills, modelling and simulation, equipment handling skills, manufacturing skills and diverse other technical competences. This diversity of technical skills goes far beyond the limits of a single individual. The majority of jobs in KETs require a technical background. What kind of technical background is needed depends on the needs of a particular job, often with a wide variety of technical backgrounds being relevant for the same job.

Academic institutions are often reported to focus on theoretical aspects, while companies require practical hands-on skills. The latter are vital for applying KETs-related technical knowledge to practice. These practical skills are related to diverse application areas that KETs are connected with. After entering the labour market, all specialists in the field of KETs need regular retraining and continuous professional development. At the same time, companies, particularly SMEs, find it challenging to provide such training.

While Vocational Education and training (VET) institutions and universities generally prepare graduates with a focus on one particular discipline, industry often needs people who are trained in various disciplines simultaneously and can work 'on the crossroads' of those disciplines. KETs are driven by multidisciplinary teams formed by people with highly diverse technical and non-technical backgrounds. KETs thus heavily rely on 'smart' combinations of people with a wide range of profiles, with many of them coming from domains not directly related to KETs.

There is a limited number of initiatives in Europe focussing explicitly on KETs skills. More often KETs skills issues are embedded in broader KETs-related initiatives or in STEM activities.

The key conclusions of our analysis within ***Thematic area 2 (Mobility)*** are as follows:

Due to a high complexity of KETs, a single person needs to have a strong expertise in one specific KET, and then a good understanding of another KET, not at the level of expert, but to be able to apply his or her primary expertise to this other area. For this, a so called 'T-shaped approach' is reported to be useful, where one discipline is acquired at a highly advanced level and basic knowledge of other relevant disciplines is present as well. Such T-shaped professionals are then put into 'smart' teams in different combinations depending on the context and needs of a specific project. A multi-KETs orientation with a specialisation in a specific KET is reported to become increasingly important also for KETs workers with VET.

People working on KETs commercialisation trajectories typically need to be engaged in several parts of the value chain simultaneously (e.g. research and demonstration & piloting; research and manufacturing). Mobility along the value chain allows for a better understanding of KETs RDI trajectories and expansion of skills portfolio, as well as higher quality feedback loops.

Geographical mobility proves to be more relevant for large companies and academia, and less relevant to SMEs and start-ups. In case of the latter two, geographical mobility occurs mostly on a project-by-project basis. Some SMEs specifically look for people who are committed to the region and do not have ambitions to be geographically mobile.

Stakeholders emphasise the need to stimulate mobility between academia and industry as two worlds with different ways of thinking and working. These exchanges are vital for effective knowledge circulation, finding common language, and building synergies on state-of-the-art theoretical and practical knowledge and skills.

The key conclusions of our analysis within ***Thematic area 3 (Entrepreneurial skills)*** are as follows:

Entrepreneurial skills imply being aware of the latest developments in fields adjacent to ones won (e.g. other countries, other technology domains, other companies) and acting quickly to pursue emerging business opportunities. Entrepreneurship in a broader sense also includes one's ability to effectively engage in deal negotiations and reach a favourable agreement, and to attract various sources of funding. This skill category also includes (basic) knowledge of Intellectual Property Rights and International Regulatory Affairs.

There is a need for a new generation of entrepreneurs in KETs domain, i.e. entrepreneurs who can further develop emerging areas such as additive manufacturing, hybrid machines etc. Currently, these areas are growing from a technological perspective, and there is a need for people who can act upon these opportunities on the market. Basic entrepreneurial skills need to be present in every single KETs worker.

When it comes to more specific entrepreneurial sills, in general, rather than trying to 'inject' entrepreneurship in every single KETs worker, employers should aim at developing a selection of

entrepreneurship champions/entrepreneurial project managers. Specific entrepreneurship training is also required for people working in Sales and Customer Support, where a good understanding of the client needs and the market is of vital importance.

Employers generally expect their workers to have entrepreneurship training already at school. However, in most cases, it does not happen. As a result, companies have to initiate programmes training diverse 'soft'/transversal skills, including entrepreneurship. Since companies often do not have enough organisational and financial resources to offer training themselves, the tasks requiring entrepreneurial skills are generally being carried out by people who already possess these skills without additional company training. People with entrepreneurial skills are in high demand among companies.

The key conclusions of our analysis within ***Thematic area 4 (HR management skills)*** are as follows:

One of the key challenges related to HR management practices in KETs is finding the right balance between short-term and medium-/long-term strategies. Also, the effectiveness of HR decisions highly depends on the definitions of required skills.

Although all KETs employers have to deal with HR-related issues, a considerable portion of them, particularly small business, do not have dedicated/traditional HR departments or people explicitly working on HR matters.

Whenever present, HR managers should complement the operational (R&D/technical) managers regarding the identification of the skills that need to be possessed by company workers. This is because operational managers are in a better position to assess the relevant technical skills that are needed for the job. At the same time, HR managers typically have a better feeling of 'soft' skills that are also of high importance.

Recommendations for Horizon 2020 NMBP Work Programme 2016-2017 (Chapter 3)

In the following paragraphs we outline the key recommendations for Horizon 202 within Thematic area 1 (Technical skills), Thematic area 2 (Mobility), Thematic area 3 (Entrepreneurial skills) and Thematic area 4 (HR management skills).

The key recommendations for Horizon 2020 within ***Thematic area 1 (Technical skills)*** are as follows:

- Encourage the consortia to include industrial partners from the relevant application areas, and increased encouragement for these industrial partners to provide skills development to other consortium members on the specifics of the application area they work with;
- Encourage the consortia to develop an eco-system in which diverse consortium partners would be allowed/encouraged to visit each other's facilities and (whenever relevant) use each other's equipment; jointly work on the solutions in one physical space on a regular basis; maximise the use of virtual collaboration tools whenever physical collaboration is not immediately possible.
- Encourage the consortium to ensure customer/end-user engagement already from the beginning of the project;
- Encourage the consortium members to engage technology students in project activities, e.g. in a form of traineeships, and increased encouragement for (industrial) consortium partners to provide involved students with introductory skills development familiarising them with the latest equipment, latest market trends and other practical developments in the field (these industrial partners would need to provide students with access to their skills development facilities).

The key recommendations for Horizon 2020 within ***Thematic area 2 (Mobility)*** are to launch calls with a multi-KET orientation, and to encourage the consortium to include partners covering closer-to-market activities (at least up to TRL 6; including prototyping, testing, demonstration and validation; but preferably covering the whole commercialisation trajectory from research to manufacturing), and to encourage the representatives of different parts of the value chain to provide skills development to other consortium members on the specifics of the phase they work on (e.g. key challenges, encountered technical limitations etc.).

The key recommendations for Horizon 2020 within ***Thematic area 3 (Entrepreneurial skills)*** are to encourage consortia to include experts with an entrepreneurial background (i.e. strong knowledge of and experience with the commercialisation trajectories of high-tech innovations, including financial, marketing and legal issues), and to encourage these experts to provide other project members with a skills development on the key entrepreneurial aspects relevant to the project in question (i.e., market analysis, key legal aspects, key financial aspects etc.).

The key recommendations for Horizon 2020 within ***Thematic area 4 (HR management skills)*** are to launch a call that aims to develop a targeted communication strategy on KETs as a field to work in, and to launch a call (multiple calls) to support the development of dedicated promotional campaigns that aim to improve the image of KETs in the society.

Recommendations for other actions and policies (Chapter 4)

In the following paragraphs we outline the key recommendations for other policy measures within Thematic area 1 (Technical skills), Thematic area 2 (Mobility), Thematic area 3 (Entrepreneurial skills) and Thematic area 4 (HR management skills).

The key recommendations for other policy measures within ***Thematic area 1 (Technical skills)*** are as follows:

Provide EU-level support to initiatives that stimulate direct involvement of industry in the education process for vocational education, Bachelor and Master students. Develop a dedicated KETs Skills Observatory, and provide EU-level support to initiatives that facilitate updating the skills of teachers, for example, by arranging exchanges of them with industry.

Provide EU-level support to initiatives that facilitate access of students to state-of-the-art equipment, and introduce European Bachelor/Master programmes where students would be allowed to spend some time at one of the academic centres of excellence as a compulsory part of their education. Also, provide EU-level support to initiatives that facilitate on-the-job training for SMEs.

The key recommendations for other policy measures within ***Thematic area 2 (Mobility)*** are to consider paying EU- and national-level attention to the unification of social measures including certificates and diplomas, and advance EU and national policies that help attracting non-EU talent (e.g., by softening salary requirements). Also, implement EU- and national-level measures that support the development of open eco-systems where academia and industry could collaborate together on a continuous and sustainable basis.

The key recommendation for other policy measures within ***Thematic area 3 (Entrepreneurial skills)*** is to provide EU- and national support to the measures training entrepreneurial adaptability already at the level of secondary school.

The key recommendation for other policy measures within ***Thematic area 4 (HR management skills)*** is to provide EU and national-level support for advancing the skills of HR personnel in academia, by, for example, developing sample protocols, standard operating procedures and guidelines which could be applied across universities.

1. Methodological aspects

The current chapter addresses the key methodological aspects relevant to the analysis. These aspects include desk-research, in-depth interviews, good practice analysis, case study development, as well as generating inputs for Horizon 2020 Work Programme, and generating inputs for other policy initiatives. We specifically focus on the encountered challenges, implemented solutions and the impact of these solutions on the final results.

1.1. Desk-research

As several other studies and initiatives have already (partially) examined the skills-related aspects for KETs, in this study, we aimed to ***maximise the use of existing work***. Our approach towards desk-research aimed to bring fragmented pieces together in a consolidated and concise analysis. We mobilised the sources that we identified during our extensive analysis of KETs Skills for DG GROW (within "Vision and Sectoral Pilot on Skills for Key Enabling Technologies") mentioned before, as well as other relevant publications found by means of targeted Internet search, using 'smart key word system' or working with multiple combinations of key words to achieve a good coverage of the most relevant publications. *Annex D* offers an overview of mobilised desk-research sources.

We employed a wide range of sources including:

- public sector reports (e.g. by the European Commission, national governments and agencies);
- industry publications (e.g. by European and national industry associations);
- academic articles (the most cited publications on the analysis of technical KETs skills); *and*
- other sources (e.g. conference and workshop proceedings).

The selection criteria for the sources included the following:

- direct relevance to the subject in question (i.e. skills in the area of KETs, and particularly NMBP);
- reliance on the employer feedback (i.e. reports and studies basing their conclusions on the inputs from (primarily) the employers' side, e.g. by means of surveys or interviews, and thereby reflecting the demand side of the market);
- credibility of the source (i.e. the source needs to be developed by renowned organisations/individuals).

Identified problem

Due to a highly specific nature of research questions of this study, the available desk-research sources on these issues proved to be highly scarce. We were able to use the literature mainly for sketching a general context for the research questions, rather than for finding direct answers.

Solution

We complemented the abovementioned desk-research with a series of in-depth interviews with the representatives of the relevant stakeholder groups. The interview questions were customised to serve the specific needs of this study and covered the exact topics in question.

Impact on the results

It was often not possible to back the findings up by citations from the prominent literature sources. At the same time, the findings are heavily based on the inputs obtained directly from the field, which significantly increases their practical relevance. Furthermore, this approach also increases the practical relevance of the recommendations derived from these findings.

1.2. Interviews

In total we conducted 21 interviews (one more than initially proposed) with the representatives of both large companies and SMEs from the NMBP areas, as well as academia, policy makers and supporting organisations. *Annex E* presents a list of interviewed stakeholders. We aimed for a good geographical balance of the organisations from the sample. We specifically targeted operational KETs managers of large companies, CEOs of SMEs and heads of laboratories (or similar) in academia, as well as coordinators of supporting initiatives (e.g. cluster organisations, industry associations or similar).

Identified problem

Not all approached stakeholders were willing to contribute to the study.

Solution

In order to maximise the effectiveness of our interview invitations, we approached the potential informants at the very early stage of the study, by clearly explaining the nature and background of the study, and the expected inputs from their side. Moreover, the use of an accompanying support letter from the Commission encouraging potential informants to contribute to the study also proved to increase the chance of their participation. Furthermore, we guaranteed impartiality in the analysis, as well as anonymity and security of data.

Impact on the results

Our final sample of interviewees consisted of people who were most willing to contribute to the study, with a genuine interest in the subject of research and direct relevance to the issues in question.

1.3. Good practice analysis

Good practice analysis conducted within the thematic area of Technical skills focused on 5 MS from different parts of Europe, with an objective to ensure a good geographical balance and a good representation of activities that currently take place. Since the majority of relevant initiatives are concentrated in Western Europe, we included in the sample 2 MS from Western Europe and 1 MS from every other European region (North, South and East). For the final selection of the MS, we employed the results of the Innovation Union Scoreboard 2014[1], and gave the preference to the MS that are among the highest innovation performers in their regions. The final sample consisted of Germany, United Kingdom, Sweden, Italy and Estonia.

For each MS from the sample, a concise overview of policies and other activities in the field of KETs skills was developed. The results of this exercise are presented in *Annex A*. We aimed to focus on the most representative activities relevant to technical KETs skills. The developed profiles consist of the following elements:

- short introduction to RDI policy of the MS;
- short overview of RDI policy specifically for KETs;
- Short overview of relevant policy measures focussing on KETs/being relevant to KETs, and specifically relevant to the aspects of KETs skills;
- Conclusion of the analysis.

In order to obtain the required information, we mobilised the Internet resources, as well as our connections to the key stakeholders in the selected MS. We applied targeted Internet search, using 'smart key word system' or working with multiple combinations of key words to achieve a good coverage of the most relevant publications/websites. We combined general policy documents with the descriptions of specific initiatives on the dedicated websites of educational institutions and industry. We specifically mobilised data and reports offered per MS by the KETs Observatory[2] (e.g. KETs policy profiles per MS listing key policy initiatives) and EU Skills Panorama[3] (although these reports are often of a more general orientation than NMBP). This approach allowed us to maximise synergies with existing projects in the field of KETs and skills.

Identified problem

KETs are not equally developed in all MS. While some MS are world-class leaders in this field, others are either followers or are demonstrating limited interest in KETs development. This situation has direct implications for the presence of good practices focussed on KETs and

[1] http://ec.europa.eu/enterprise/policies/innovation/policy/innovation-scoreboard/index_en.htm

[2] https://webgate.ec.europa.eu/ketsobservatory/

[3] http://euskillspanorama.cedefop.europa.eu/KeyIndicators/Country/Details.aspx?nationalcountryid=11&

specifically KETs skills. MS from Western and Northern Europe are more likely to have a wide range of measures that are of interest to this study than Eastern and Southern Europe.

Solution

Also in the latter two regions, some relevant good practice examples can still be found. Furthermore, these good practices are likely to have a higher transferability level to other MS from the same European region than good practices from other European regions. Therefore, after a consultation with the Commission, it has been decided to proceed with the initial approach of focussing on 5 MS from all four European regions.

Impact on the results

As we followed the initial approach, we were able to achieve a good geographical balance of the identified good practices.

In addition to good practice analysis for technical KETs skills, we also collected good practices related to fostering mobility in KETs. These good practices are based on interview results, and were nominated directly by the stakeholders. In this case, we did not explicitly focus on five MS mentioned above; instead, we offered stakeholders an open platform for naming the practices they think should be incorporated into our analysis (independent of their geographical origin; all good practices nevertheless come from Europe). The results of this exercise are presented in Annex B.

1.4. Development of case studies

As mentioned above, the literature on the posed research questions is highly limited (for NMBP field), and therefore there is a need to build on empirical data from the field. As a result, we developed empirical case studies on HR management practices based on the interview data from a selection of KETs stakeholders. We developed concise case studies covering the main details of the approach, including the essence of the approach, and its implications for the skills portfolio, as well as associated challenges and constraints. The results of this exercise are presented in Annex C.

Identified problem

Our initial proposal was to develop case studies per identified approach. However, in the course of our analysis, we concluded that even the same approach implemented in different settings can have different implications and constraints.

Solution

We developed case studies based on organisation (while specific names of organisations are not being disclosed in the analysis due to anonymity guarantee of the results), we indicate the type of organisation, its size and the relevant KET(s) it works in, in order to specify the relevant context.

Impact on the results

Generated findings take better account of diverse contexts in which analysed approached can be implemented, which increases the practical relevance of the results.

1.5. Generating recommendations for Horizon 2020 NMBP Work Programme

The output of this exercise includes the guidelines listing the main issues and most significant measures to be included in the Horizon 2020 Work Programme and topic descriptions.

We will particularly aimed at:

- offering a "menu of actions" for all four thematic areas in question;
- addressing the issue of integration across various NMBP areas;
- addressing the role of all key stakeholder groups, including policy makers, educators and industry, and particularly SMEs;
- emphasising the facilitator role of policy makers and elaborating on the environment, institutions and support tools that can be put in place in order to facilitate a transformation of the current systems;
- viewing the guidelines from a perspective of a whole policy mix (i.e. keeping in mind other on-going initiatives) rather than as a set of isolated measures.

Identified problem

Although all KETs employers have to deal with HR-related issues, a considerable portion of them, particularly small business, do not have dedicated/traditional HR departments or people explicitly working on HR matters. Instead, HR management is typically carried out by CEOs or operational managers in additional to a wide variety of other tasks. Therefore, a general advice regarding HR management practices would hardly be relevant here. It proved to be a challenge to develop generalised inputs on HR management practices for Horizon 2020 that would be relevant for all KETs employers.

Solution

At the same time, we were able to find commonalities in the issues that KETs employers have to deal with when it comes to attracting and retaining personnel. These include a low awareness of the society about KETs as a field to work in, and a relatively unattractive image of KETs.

Impact on the results

Instead of focussing on recommendations for specific HR management practices, we included a set of additional measures in the analysis that allow to tackle the abovementioned challenges on a massive scale. Supporting these measures within the Horizon 2020 Programme would address the issue of common European interest.

1.6. Generating inputs for other actions and policies

We also generated suggestions for other relevant measures at the level of Research & Innovation policy that could help tackle skills imbalances in KETs. The output here refers to suggestions for other actions, including further studies (investigations and conceptual activities), as well as other policy measures. We focussed on policy measures where European dimension is particularly important; however, we also addressed the role of stakeholders at other levels, including national and regional policy levels, as well as educators, and industry (and particularly SMEs). Additionally, suggestions for future studies include topics where additional research is needed at the EU level.

Identified problem

In the course of our analysis, we were able to identify a wide variety of different other policy measures that would help tackling KETs skills-related issues. Some of them are of broader orientation, while others exclusively focus on KETs, and particularly NMBP. Not all of the identified measures were of equal importance to our analysis.

Solution

In order to keep our analysis focussed, we had to be selective and set priorities for the measures that need to be elaborated in the report for this study. We developed a selection of measures that are of the highest relevance to the NMBP areas, and that are of common European interest and focus explicitly on skills.

Impact on the results

The presented selection of other policy measures has a dedicated focus on skills in the NMPB areas, with a clear European dimension.

2. KEY FINDINGS

The current chapter provides an overview of the key findings that are based on desk-research and interview series conducted in the course of the study. The findings serve as a knowledge base for extracting specific recommendations for the NMBP Work Programme of Horizon 2020, as well as for other policy initiatives. The findings are structured around the four thematic areas, and cover all research questions. In the current chapter, we explicitly focus on the analytical conclusions. Specific recommendations are presented in the sub-sequent two chapters.

2.1. Thematic area 1: Technical skills

The analysis within thematic area 1 aimed to develop inputs for specific actions and recommendations on how to ensure a better alignment of educational and skills development systems for technical skills with employers' needs and constraints in the NMBP areas. Specific activities carried out within this Task included identifying key technical skill requirements for KETs, identifying key areas of mismatch, and mapping activities related to technical KETs skills in Europe. The findings for this thematic area were extracted by means of targeted desk-research, complemented by additional stakeholder remarks during the interview series.

Technical skills here refer to knowledge of scientific/technological areas including methodological competences for one to be able to handle technical processes.

RQ1.1 What key technical skill requirements are there for KETs?

In a parallel study on "Vision and Sectoral Pilot on Skills for Key Enabling Technologies"[4], that we are currently carrying out for DG GROW of the European Commission, we showed that technical skills for KETs can be split into several sub-categories related to scientific/technical background, design, ICT skills, modelling and simulation, equipment handling skills, manufacturing skills and diverse other technical competences. Also, the relevance of specific skills differs across the three pillars in KETs, being technological research (Pillar I), product development (Pillar II) and competitive manufacturing (Pillar III). This diversity of technical skills goes far beyond the limits of a single individual. Below we provide a short recap of technical skill requirements for KETs.

The majority of jobs in KETs require having a technical background. What kind of technical background is needed depends on the needs of a particular job, often with a wide variety of technical backgrounds being relevant for the same job. The higher the degree of specialisation of a job profile in question, the more specific educational background is usually required (although, lack of relevant educational background can often be compensated by sufficient work experience in the required field). Backgrounds with a more general orientation typically include physics, mathematics, engineering, computer science and chemistry (KETs thus heavily rely on people from general STEM domains). Backgrounds in nanoscience and materials science are linked to a higher degree of specialisation both during the educational process and on the job.

Design-related competences refer to the skills and knowledge of design techniques, tools, and principles involved in production of technical plans, blueprints, and models. Technically challenging and complex products developed within KETs require mastering advanced design skills including a good knowledge of design methodology, operations and systems analysis, Computer-Aided Design (CAD), multidisciplinary design optimisation, scalability analysis and life-cycle analysis. The latter refers to the ability to assess environmental impacts associated with all the stages of a product's life from-cradle-to-grave.

Furthermore, given a heavy reliance of KETs on the state-of-the-art ICT solutions, including advanced CAD tools, tools for prototyping and testing, tools for manufacturing and process optimisation etc., individuals working in KETs typically need to master cutting-edge ICT skills. The latter include basic computer skills, but also varying degrees of programming skills and computation thinking. Computational thinking here means the ability to translate vast amounts of data into abstract concepts and to understand data-based reasoning. Diverse other relevant technical competences include, for example, characterisation and analysis, general and specific lab skills and systems integration.

[4] PwC (2014) "Vision and Sectoral Pilot on Skills for Key Enabling Technologies", Interim Report, prepared for DG GROW of the European Commission, Service contract nr. SI2.ACPROCE060233200

Additionally, modelling and simulation competences prove to be particularly relevant for the product development pillar (Pillar II) in KETs. These competences refer to skills and knowledge of, for example, mathematical modelling and simulation, Computer-Aided Engineering (CAE), non-destructive testing and real-time modelling and simulations.

The competitive manufacturing pillar (Pillar III) in KETs implies organising and running highly complex manufacturing processes which have direct implications for the skill needs. However, the key focus of the current study is on research and development, and in our analysis, we will address the manufacturing-related technical skills to the extent when these are relevant for research and development activities (i.e. Pillars I and II; manufacturing skills related to demonstration and piloting activities and embedded in research and development).

As for the future technical skills for KETs, in our Interim Report for "Vision and Sectoral Pilot on Skills for Key Enabling Technologies: key findings of Phase one"[5], we emphasised that, given a rapidly expanding amount of knowledge within KETs, it is not exclusively knowledge and skills themselves that need to be taught to students, but primarily the ability to absorb and constantly update knowledge and skills, as well as to create new knowledge and skills on top of it all, i.e. learning-to-learn competence.

RQ1.2 What are the key areas of mismatch?

Specific technical areas of KETs skills that require more attention than is currently being paid by the educational institutions include quality & safety aspects, regulatory aspects and equipment handling skills.

There are only a few studies exploring the key areas of mismatch in KETs. These studies are mainly focussed on nanotechnology. For example, a report by NanoEIS ("Nanotechnology Education for Industry and Society")[6] concluded that nanotech companies currently experience a lack of nanospecific knowledge. Among the specific technical skills that are considered to be the most important, general knowledge of health and safety issues was mentioned as the most popular, followed by knowledge of nanocoatings/smart surfaces and characterisation techniques[7]. Furthermore, education in universities was reported to be seen as too theoretical, lacking practical orientation. Finally, a scarcity of skilled staff with experience in technology transfer was mentioned as a challenge.

The same report projects that in five years' time, health and safety issues will still be among the most required skills, followed by regulation and standardisation, environment/disposal/recycling and nanochemistry.

An earlier survey by Institute of Nanotechnology[8] indicated that experience with handling the equipment used in nanotechnology is invaluable, together with knowledge of contamination and safety issues, as well as nanofabrication quality control.

It is rather the novelty of knowledge and skills that are being trained by the educational institutions what represents a challenge for KETs, not exclusively the type of knowledge and skills

It takes more than a decade for individuals to acquire KETs-related technical knowledge and skills. However, with a tremendous pace of development in KETs, the acquired knowledge and skills quickly become obsolete. Furthermore, students often have to work with the software and

[5] PwC (2014) "Vision and Sectoral Pilot on Skills for Key Enabling Technologies", Interim Report, prepared for DG GROW of the European Commission, Service contract nr. SI2.ACPROCE060233200

[6] http://www.nanoeis.eu/sites/nanoeis.eu/files/downloads/NANOEIS%20D2.1%20Report%20on%20European%20industry%20needs.pdf

[7] See also Invernizzi, N. (2011) "Nanotechnology between the lab and the shop floor: what are the effects on labor?" Journal of Nanoparticle Research, 13(6), 2249-2268

[8] Singh K.A. (2007) "Nanotechnology skills and training survey", Institute of Nanotechnology

equipment that are already outdated, without having access to the state-of-the-art developments, and thus entering the labour market with knowledge and skills that are already out-of-date[9].

Theoretical foundations often are not being sufficiently translated by educational institutions into practical implications

Academic institutions are often reported to focus on theoretical aspects, while companies require practical hands-on skills. The latter are vital for applying KETs-related technical knowledge to practice. These practical skills are related to diverse application areas that KETs are connected with, but despite their practical orientation, they are also highly knowledge-intensive relying on firm theoretical foundations. Stakeholders report a need for teams with a combination of both in-depth technical knowledge and a good understanding of the basic characteristics of specific application areas[10].

Therefore, another type of mismatch emerges where theoretical foundations are not being sufficiently translated by educational institutions into practical implications. Stakeholders report a need for graduates with a broad set of interest and sufficient understanding of the basic characteristics of certain application areas[11].

A mismatch emerges also because all KETs workers need regular retraining and continuous professional development (i.e. life-long learning); at the same time, companies, particularly SMEs, find it challenging to provide such training.

After entering the labour market, all specialists in the field of KETs need regular retraining and continuous professional development (i.e. life-long learning). At the same time, companies, particularly SMEs, find it challenging to provide such training. Skills development is a costly activity, and the resources that SMEs can spend on skills development are typically highly limited in terms of both time and money. Secondly, there is often a lack of organisational capacity within SMEs including human and intellectual resources to provide such skills development[12].

KETs require skills development in various disciplines simultaneously and the ability to work 'on the crossroads' of those disciplines

Stakeholders report that while VET institutions and universities generally prepare graduates with a focus on one particular discipline, industry often needs people who are trained in various disciplines simultaneously and can work 'on the crossroads' of those disciplines. Up until now, people were trained either in mechanics, electrics or systems engineering. However, industry needs employees who are trained in all three aspects simultaneously, i.e. mechatronics[13].

KETs are driven by multidisciplinary teams formed by people with highly diverse technical and non-technical backgrounds. KETs thus heavily rely on 'smart' combinations of people with a wide range of profiles, with many of them coming from domains not directly related to KETs, particularly when it comes to specific application areas[14]. Consequently, new ways of project design and management are needed going beyond the traditional 'silos' approach and facilitating the identification of linkages between previously unconnected fields and diversity of profiles of team members.

RQ1.3 What diverse activities currently take place in Europe to foster the development of KETs skills?

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[9] PwC (2014) "Vision and Sectoral Pilot on Skills for Key Enabling Technologies", Interim Report, prepared for DG GROW of the European Commission, Service contract nr. SI2.ACPROCE060233200

[10] Based on interviews

[11] See also SEMTA (2009) "Skills and the future of Advanced Manufacturing: A Summary Skills Assessment for the SSC Advanced Manufacturing Cluster", December 2009

[12] CECIMO (2013) The European machine tool industry's Manifesto on skills, September 2013

[13] Outputs of the workshop on KETs Skills organised by KETs HLG Sherpa Group of 10 June 2014

[14] Outputs of the workshop on KETs Skills organised by KETs HLG Sherpa Group of 10 June 2014

Within this Research Question, we aimed to explore diverse activities currently take place in Europe to foster the development of KETs skills. We worked with a sample of five Member States that include Germany, the United Kingdom, Sweden, Italy and Estonia. For the final selection of the MS, we employed the results of the Innovation Union Scoreboard 2014[15], and gave preference to the MS that are among the highest innovation performers in their regions. The results of our analysis are presented in *Annex A* of this report.

Our analysis showed that there is a limited number of initiatives focussing explicitly on KETs skills. More often KETs skills issues are embedded in broader KETs-related initiatives. Furthermore, KETs-related initiatives themselves are limited in number, and since KETs heavily rely on people from general STEM domains, we also explored the presence of major STEM-related initiatives that could have direct relevance to KETs skills. Annex A presents an inventory of good practice examples from the abovementioned five Member States. This overview is based on targeted desk-research, and heavily builds on the policy profiles developed by a parallel project of DG GROW, KETs Observatory[16].

The answers to RQ1.4-1.5, as well as other RQs related to specific recommendations are presented in the sub-sequent chapters.

2.2. Thematic area 2: Mobility

The analysis within this thematic area aimed to develop inputs for specific actions and recommendations on how to stimulate diverse types of mobility in the NMBP areas in order to strengthen skills portfolio. Specific activities carried out within this Task included identifying key types of mobility vital for KETs, identifying the ways to encourage mobility, identifying good practices and assessing their transferability.

The findings for this thematic area were collected by means of in-depth interviews with the representatives of relevant stakeholder groups, complemented by targeted desk-research.

Our general observation is that mobility is an essential element to the world of KETs. In addition to the professional and personal experiences that KETs workers can benefit from, mobility allows them to join the most talented colleagues in their field, anywhere in the world. Mobility gives KETs workers an opportunity to expand their knowledge and diversify their skills. It also enables them to progress with their careers. Finally, mobility allows getting access to state-of-the-art knowledge, skills, and equipment, thereby solving the issue of knowledge quickly becoming obsolete.

RQ2.1 What types of mobility are vital for KETs?

While mobility between KETs favours interdisciplinary/cross-cutting acquisition of competences, KETs benefit more from creating 'smart' teams rather than just 'smart' individuals knowing the aspects of several KETs simultaneously.

Our analysis suggested that ***mobility between KETs*** (e.g. from Nanosciences to Materials Sciences, or from Materials Sciences to Production Processes etc.) favours interdisciplinary/cross-cutting acquisition of competences, multidisciplinary scientists or middle managers. By enlarging the professional profile of experts, mobility can help mitigating shortages in the most critical NMBP fields. However, in general, stakeholders almost unanimously agree that due to a high complexity of KETs, a single person needs to have a strong expertise in one specific KET, and then a good understanding of another KET, not at the level of expert, but to be able to apply his or her primary expertise to this other area. Achieving this balance of skills in KETs workers, however, proves to be a challenge for employers.

A so called 'T-shaped approach' is reported to be useful, where one discipline is acquired at a highly advanced level and basic knowledge of other relevant disciplines is present as well. Such T-shaped professionals are then put into 'smart' teams in different combinations depending on the context and needs of a specific project.

Furthermore, a multi-KETs orientation with a specialisation in a specific KET is reported to become increasingly important also for KETs workers with Vocational Education and Training (VET). For example, machine operators increasingly need to have a good knowledge of advanced ICT tools,

[15] http://ec.europa.eu/enterprise/policies/innovation/policy/innovation-scoreboard/index_en.htm

[16] https://webgate.ec.europa.eu/ketsobservatory/

understand the ways of working of networked factories, as well as have knowledge of specific highly sophisticated manufacturing processes (e.g. laser-based manufacturing). Consequently, it is not only highly skilled workers who need a multidisciplinary orientation.

At the same time, people at the shop floor level [with lower educational levels] are typically more reluctant to engage in mobility/rotation across KETs because of a number of factors. First, they often need additional skills development as their initial skills development is typically highly specialised. Second, these workers often lack key 'soft' competences including communication skills which are needed in different fields. Third, these workers often work in a high-control environment designed by higher management which limits the mobility of workers. Managers [who typically have higher educational levels] and researchers are easier to rotate as they possess the abovementioned key competences needed for mobility.

For obtaining knowledge and skills of different application areas, a 'smart' mixture of teams may be more appropriate for KETs than job rotation.

KETs are related to an endless number of application areas, and the link with these areas is at least as important as the link with other KETs. This link includes mobility beyond KETs, to diverse application areas. In our Interim Report for "Vision and Sectoral Pilot on Skills for Key Enabling Technologies" [17], we emphasised that KETs deployment requires the emergence of teams with a mix of skills that in most cases has never been formed before (e.g. for integrating KETs into cow milking business, edible pills, training suits etc.). The potential of KETs for an endless number of application areas thus implies that KETs commercialisation trajectories heavily rely on knowledge and skills from literally every field of life. The mobility of workers beyond KETs to diverse application areas can thus be an important means to fully benefit from KETs potential.

In general, stakeholders almost unanimously agree that a single person needs to have a strong expertise in one specific KET, and then a good understanding of a certain application area, not at the level of expert, but to be able to apply his or her primary expertise to this other area. Achieving this balance of skills in KETs workers, however, proves to be a challenge for employers.

Stakeholders confirmed that, in general, a 'smart' mixture of teams proves to work better than job rotation. However, it may be difficult to accomplish within SMEs and teams, where the cost of bringing together a representative from all relevant disciplines might be unaffordable[18]. A popular solution in this case is partnering with other companies working specifically within the relevant application areas. Additionally, working directly with end-users proves to be a highly valuable approach for increasing the commercial potential of the innovation in question. Practitioners can be directly asked what exact needs they have, how they think the market is going to evolve etc.

Mobility along the KETs value chain is especially valuable for project managers who are assigned responsibility for the whole product/process development trajectory

There is a complex nature of relationships between various steps of KETs value chain (i.e. multiple feedback loops; activities happening in parallel etc.)[19]. These complex relationships have direct implications for the skill requirements. Instead of distinctive skill-sets corresponding to each step of the value chain, the empirical evidence shows a clear interrelationship of required skills among these steps, with multiple connections and significant overlaps[20].

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[17] PwC (2014) "Vision and Sectoral Pilot on Skills for Key Enabling Technologies", Interim Report, prepared for DG GROW of the European Commission, Service contract nr. SI2.ACPROCE060233200

[18] SEMTA (2009) "Skills and the future of Advanced Manufacturing: A Summary Skills Assessment for the SSC Advanced Manufacturing Cluster", December 2009

[19] PwC (2013) Study on "Open innovation and enabling technologies: Analysis of conditions for transfer of knowledge", prepared for DG RTD of the European Commission, service contract nr NMP1-SC-2011-IN0002, available at: http://ec.europa.eu/research/industrial_technologies/pdf/how-to-convert-research-into-commercial-story-part2_en.pdf

[20] PwC (2014) "Vision and Sectoral Pilot on Skills for Key Enabling Technologies", Interim Report, prepared for DG GROW of the European Commission, Service contract nr. SI2.ACPROCE060233200

People working on KETs commercialisation trajectories typically need to be engaged in several parts of the value chain simultaneously (e.g. research and demonstration & piloting; research and manufacturing). Mobility along the value chain allows for a better understanding of KETs RDI trajectories and expansion of skills portfolio, as well as higher quality feedback loops. Achieving this balance of skills in KETs workers, however, proves to be a challenge for employers.

In general, this type of mobility is relevant for a wide variety of KETs workers, including researchers. At the same time, this type of mobility proves to be especially valuable for project managers who are assigned responsibility for the whole product/process development trajectory. However, it is easier to implement if the value chain is within one company or if there is a limited number of supply chain actors. For example, many large companies have integrated their research and production activities in one facility, thereby facilitating the process of interconnected collaboration of people from different parts of the value chain.

While geographical mobility has a lot of benefits, it also has significant implications for the employee and the employer, and these implications make this type of mobility less attractive for both sides.

By sharing knowledge between different (research) organisations, geographical mobility encourages the setting up of researcher networks and the development of transnational and/or inter-sectoral collaborations. Geographical mobility is particularly supported for academic staff.

At the same time, company employees are often reluctant to move abroad even for a relatively short time period. While there is a small portion of individuals who do choose geographical mobility, they are typically a minority of all workers. Additionally, middle-managers often advise against this type of mobility as they are afraid of losing their best people. The mobility programmes typically take 1-2 years, and it requires these managers to fill a position with someone else with no guarantee that the initial person will ever want to come back.

Geographical mobility proves to be particularly challenging for people with lower educational levels (e.g. cleanroom operators, other machine operators). These people in general have limited language skills [they often speak only their native language], while at the shop floor level, the language of the host country typically needs to be spoken.

Geographical mobility proves to be more relevant for large companies and academia (it is popular among Master students and PhDs), and less relevant to SMEs and start-ups. In case of the latter two, geographical mobility occurs mostly on a project-by-project basis. Within projects for, for example, large companies, KETs workers are sometimes required to work on-site at client's facilities all over the world. At the same time, some SMEs specifically look for people who are committed to the region and do not have ambitions to be geographically mobile.

All the above-mentioned mobility types could be better facilitated through exchanges between academia and industry.

The engaged stakeholders almost unanimously emphasised the need to stimulate the mobility between academia and industry as two worlds with different ways of thinking and working. These exchanges are vital for effective knowledge circulation, finding common language, and building synergies on state-of-the-art theoretical and practical knowledge and skills.

At the same time, stakeholders also report that joint projects alone are not sufficient to bridge the gap between people with research and industrial backgrounds. They mention examples of projects where industry people work with researchers for several years now; however, it does not seem to be sufficient to change the mind-set of any of them.

Sending researchers to spend some time in industry also often proves to be difficult. Partner companies, in general, find it acceptable to host researchers there; however, they are typically cautious about letting those researchers see how they work in detail. This has to do with trade secrets where outsiders are not allowed.

Consequently, there is a clear need for developing open eco-systems where academia and industry could collaborate together on a continuous and sustainable basis (not just on a project basis).

RQ2.2 How, when and by whom can these different types of mobility be encouraged during education and career?

A key way to stimulate mobility in KETs is to guarantee workers a top-quality working environment in the new role/place (e.g. well-equipped laboratories, generous budgets and a high level of autonomy).

Mobility is more feasible to encourage in large companies and academia than in SMEs. Not all the employers share the view that personnel mobility is beneficial for their companies. It particularly refers to their 'star' employees whom they do not want to lose to other departments/regions/countries/ companies etc.

RQ2.3 What good practices can be identified where mobility in KETs is effectively stimulated?

Annex B presents examples of five good practices that we collected in the course of our analysis. These good practice examples were nominated by the interviewed stakeholders. These examples cover different types of mobility in KETs.

The first example refers to VDW-Nachwuchsstiftung (Youth Education and Development Foundation) in Germany. This initiative aims at fostering mobility between industry, vocational schools and universities within the machine tool sector. The Foundation offers around applied skills development courses with the help of machines and latest technologies for vocational school teachers and company skills development instructors. The courses are organised in partnership with Siemens and Heidenhain at their skills development centres.

The second example refers to AFM traineeship initiative in Spain. It illustrates how a business association supports traineeship mobility in Advanced Manufacturing Technologies (AMT). The initiative aims to send recently graduated young people abroad for gaining work experience in the field of AMT before they can join host companies in Spain.

The third example refers to IMH (the Machine Tool Institute) in Spain. It illustrates how companies and education providers cooperate at regional/national level through a business association by stimulating mobility between industry and academia. Specifically, the Dual Engineering University School of IMH offers an engineering university course combining academic training and gaining work experience in a company. This is an innovative study option which is directly related to the fact that companies require a workforce that is tailor-made to meet their needs.

The next two examples refer to the EU initiatives stimulating mobility, namely Marie Curie Actions Initial Training Networks (ITN) and Research and Innovation Staff Exchange (RISE). ITN aims to strengthen the links between academia and industry, and to develop research careers combining scientific excellence with business innovation. Stakeholders also expressed their strong support for a similar programme for industry-industry exchange, for instance between large companies and SMEs that operate within the same KETs-related value chain.

RISE funds short-term exchanges for staff to develop careers combining scientific excellence with exposure to other countries and sectors. RISE enables more interaction between academia and non-academic organisations within Europe and worldwide.

RQ2.4 To what extent are these good practices transferable to other contexts

While the last two good practices are already available at the European level, the first three are still only available locally. Nevertheless, these three good practices are transferable to other MS, as they proved not to be heavily dependent on specific contextual issues.

The first three examples are of higher relevance for people with VET, the latter two are focussing on highly educated KETs workers. Stakeholders emphasised a need to pay additional attention at the European level to middle-skilled workers (VET) and to introduce specific programmes targeting this group.

The identified local good practices can also be transferred to different KETs, as the issues they are tackling are relevant to all NMBP areas. These examples illustrate how different stakeholder groups can join forces in order to tackle skills issues of common interest, and specifically emphasise the role of business associations.

2.3. Thematic area 3: Entrepreneurial skills

The analysis within thematic area 3 aimed to develop inputs for specific actions and recommendations on how to enhance the acquisition of entrepreneurial skills among NMBP workers and on the way industry (especially SMEs) could be involved in the process. Specific activities that were carried out within this Task included identifying relevant entrepreneurial skills for KETs, analysing the implications of strategic company choices, analysing key constraints resulting from strategic choices, identifying the ways to acquire entrepreneurial skills, and identifying the role of industry (and particularly SMEs) in developing/stimulating entrepreneurial skills.

The findings for this thematic area were collected by means of in-depth interviews with the representatives of relevant stakeholder groups, complemented by targeted desk-research.

RQ3.1 What entrepreneurial skills deserve systematic support and development for young people, researchers and industry staff to help them detect and develop business opportunities from RDI based on KETs?

Entrepreneurial skills imply staying up-to-date to the extent possible (as the large coverage of the KETs domain does not allow for a full awareness of all current developments) and acting quickly to pursue emerging business opportunities. Entrepreneurship in a broader sense also includes one's ability to effectively engage in deal negotiations and reach a favourable agreement, and to attract various sources of funding (e.g. public grants, venture capital etc.). This skill category also includes (basic) knowledge of Intellectual Property Rights and International Regulatory Affairs. Entrepreneurial skills are closely related to management, communication and innovation skills[21], as well as emotional intelligence[22].

Additionally, there is a need for a new generation of entrepreneurs in KETs domain, i.e. entrepreneurs who can further develop emerging areas such as additive manufacturing, hybrid machines etc. Currently, these areas are growing from a technological perspective, and there is a need for people who can act upon these opportunities on the market. There is a need for a combination of general entrepreneurial skills and a good knowledge of these new technologies.

RQ3.2 What strategic choices of companies facilitate the acquisition and maintenance of entrepreneurial skills?

In general, rather than trying to 'inject' entrepreneurship in every single KETs worker, employers should aim at developing a selection of entrepreneurial project managers

Stakeholders almost unanimously agree that basic entrepreneurial skills (i.e. basic understanding of the market developments and the existence of market pull (besides technology push), ability to present ideas in a convincing way, ability to detect potential market for a new technology etc.) need to be present in every single KETs worker. The current KETs workers are often reported to lack these basic skills. General awareness raising and development of basic entrepreneurial skills for all employees is likely to increase the quality of the workforce and boost the commercialisation outputs.

Stakeholders emphasise the importance of working on opening up the minds of people and making them aware of entrepreneurial opportunities and how to act upon those. It is, however, more needed for their research work (e.g. to increase its practical applicability) rather than for doing hard-core business development. Then, for those who are interested, skills development needs to be provided allowing them to develop their entrepreneurial skills at a more advanced level. It is thus more about creating specific skills development opportunities for those who want rather than imposing it on everybody.

Consequently, when it comes to more specific entrepreneurial skills (see skills listed in the answer to RQ3.1), in general, rather than trying to 'inject' entrepreneurship in every single KETs worker, employers should aim at developing a selection of entrepreneurship champions/entrepreneurial project managers. This approach combined with a practice of 'attaching' these people to the whole

[21] i.e. skills related to design and creation of new things (e.g. integration skills, complex problem solving, creativity, systems thinking)

[22] i.e. the ability to operate with own and other people's emotions, and to use emotional information to guide thinking and behavior

development and commercialisation trajectory is likely to maximise the effect of the abovementioned skills and create a higher sense of ownership of the assigned task.

Specific entrepreneurship skills development is also required for people working in Sales and Customer Support, where a good understanding of the client needs and the market is of vital importance.

RQ3.3 What are the key constraints resulting from these strategic choices?

Ideally, KETs companies should not make any choices, but combine both strategies, i.e. developing basic entrepreneurial skills in all workers, and then offering a more in-depth skills development to the ones willing to advance these skills even further. However, skills development is a costly activity requiring also significant organisational resources, and companies, particularly SMEs, often cannot afford following this comprehensive strategy.

RQ3.4 How and at what point of time can those skills best be acquired?

Entrepreneurial skills can typically be mastered well if the person possesses a so called 'innate entrepreneurial spirit'.

One of the key challenges related to entrepreneurial skills is that these skills can typically be mastered well if the person possesses a so called 'innate entrepreneurial spirit'. The latter refers to a natural predisposition of the person to engage in entrepreneurial activities in a broader sense, due to a certain inborn character that the educational and training systems can only build on and encourage. Currently, intensive discussions take place between stakeholders on whether or not entrepreneurship can be taught, with a general agreement that some people are more inclined to engage in entrepreneurship than others, due to specific character traits. Nevertheless, empirical evidence shows that some entrepreneurial skills can be taught, and an increasing number of courses and skills development programmes becomes available to KETs workers.

Employers generally expect their workers to be trained already at school. However, in most cases, it does not happen. As a result, companies have to initiate programmes developing diverse 'soft'/transversal skills, including entrepreneurship. However, companies often do not have enough organisational and financial resources to do so, particularly SMEs that cannot easily forego the productive work done by their specialists. In this case, the tasks requiring entrepreneurial skills are being carried out by people who already possess these skills without additional company skills development. That is why people with entrepreneurial skills are in high demand among companies.

Stakeholders thus suggest that those who want to get closer to industry (e.g. create a start-up or have a career in industry) should be offered an opportunity to train their entrepreneurial skills already during their studies. At the same time, it should not come at the expense of the quality of technical skills of new graduates.

RQ3.5 What role can industry (especially SMEs) play in the development of entrepreneurial skills?

Companies (especially SMEs) heavily depend on educational institutions/supporting structures when it comes to developing entrepreneurial skills

As mentioned above, similarly to technical skills development, companies, particularly SMEs, find it challenging to provide entrepreneurial skills development. Skills development is a costly activity, and the resources that SMEs can spend on skills development are typically highly limited in terms of both time and money. Secondly, there is often a lack of organisational capacity within SMEs[23] including human and intellectual resources to provide such skills development.

A possible solution here could be to employ these project managers as "entrepreneurship ambassadors" in their respective departments/projects. In this role, they could 'radiate' entrepreneurship values among other employees their work with, thereby raising the entrepreneurial spirit of the organisation at a relatively limited cost.

SMEs could contribute by sharing entrepreneurial success stories with students and current KETs workers.

[23] CECIMO (2013) The European machine tool industry's Manifesto on skills, September 2013

Students and KETs workers rarely get an opportunity to meet and learn from successful entrepreneurs (which often come from SMEs). Entrepreneurs in this case do not only refer to people who created their own companies, but also to experts with a broader entrepreneurial orientation, including specialists in market analysis, market strategy development, financial and legal aspects. Such exposure to successful entrepreneurs/entrepreneurship experts would increase awareness about the entrepreneurial opportunities of KETs and thus boost the commercialisation potential of KETs-related ideas.

2.4. Thematic area 4: HR management skills

The analysis within this thematic area aimed to develop inputs for specific actions and recommendations on how HR managers could ensure the best use and development of skills portfolio in their organisations. Specific activities that were carried out within this task included identifying approaches to optimise skills portfolio and identifying specific HR management skills.

The findings for this thematic area were collected by means of in-depth interviews with the representatives of relevant stakeholder groups, complemented by targeted desk-research.

RQ4.1 What approaches/measures can HR managers use to optimise the skills portfolio in their organisations?

KETs companies apply a wide range of approaches towards attracting, selecting, training and retaining their employees; there is no "one best way to do things", and different organisations apply different strategies related to their needs and context.

One of the key challenges related to HR management practices in KETs is finding the right balance between short-term and medium-/long-term strategies. On the one hand, companies heavily rely on the skills that are immediately usable, which also directly influences their hiring priorities. On the other hand, sustainable development requires thinking ahead and getting prepared for the skills issues of the future already today. That includes investment in skill development of the current personnel, anticipating future skill needs and making strategic choices of how to acquire these skills.

Furthermore, the effectiveness of HR decisions highly depends on the definitions of required skills. Inappropriate definitions of the needed skills, as well as imposed limitations in terms of age, gender and other social aspects may negatively influence the skills portfolio of an organisation.

Although all KETs employers have to deal with HR-related issues, a considerable portion of them, particularly small business, do not have dedicated/traditional HR departments or people explicitly working on HR matters. Instead, HR management is typically carried out by CEOs or operational managers in additional to a wide variety of other tasks. Therefore, a general advice regarding HR management practices would hardly be relevant here.

Annex C presents 5 empirical case studies on HR management practices based on the interview data from a selection of KETs stakeholders. We developed concise case studies covering the main details of the approach, including the essence of the approach, and its implications for the skills portfolio, as well as associated challenges and constraints.

Common issues that KETs employers have to deal with when it comes to attracting and retaining personnel refer to a low awareness of the society about KETs as a field to work in and a relatively unattractive image of KETs. Below we address these topics in more detail.

RQ4.2 What specific skills do HR managers have to possess to best facilitate the development of KETs?

HR managers are expected to be strategic partners to CEOs.

KETs radically change the way many industries work. These changes have direct implications for the jobs, and specifically the types of employees needed, the tools those employees use and the skills development those employees need. Consequently, whether an organisation will be able to keep and strengthen its competitive position in the future heavily depends on its HR policies already today. HR managers are expected to be strategic partners to CEOs and "change agents" [24].

[24] Karami, A., Jones, B. M., & Kakabadse, N. (2008) "Does strategic human resource management matter in high-tech sector? Some learning points for SME managers", Corporate governance, 8(1), 7-17.

They need to facilitate the process of fully integrating KETs into the current processes and structures of their organisations.

Whenever present, HR managers should complement the operational (R&D/technical) managers regarding the identification of the skills that need to be possessed by company workers. Operational managers are in a better position to assess the relevant technical skills that are needed for the job. At the same time, HR managers typically have a better feeling of 'soft' skills (e.g. communication skills, entrepreneurial skills, management skills etc.) that are also of high importance. Consequently, HR managers should work together with operational managers in order to optimise the company's skills portfolio.

3. RECOMMENDATIONS FOR HORIZON 2020 NMBP WORK PROGRAMME 2016-2017

This chapter presents recommendations on how Horizon 2020 can help tackle the issue of skills imbalances in the NMBP areas. The recommendations were developed in a form of guidelines listing the main issues and most significant measures to be included in the Horizon 2020 NMBP Work Programme and topic descriptions.

The inputs aim to be primarily used for fostering skill-related activities in research-based projects, while also considering an opportunity to embed the skills aspects into the monitoring activities of such projects. Another intention is to expand the variety of project beneficiaries and include other relevant groups of stakeholders, not previously included.

Each topic in this chapter reflects a specific objective within each of the four thematic areas covered by the study. Within each topic, we formulate a specific challenge, and then elaborate on a proposed scope of measures and expected impact of these measures.

3.1. Thematic area 1: Technical skills

In this sub-section, we present the topics aiming to tackle the issues within thematic area 1, namely Technical skills.

Enhancing practical orientation of technical KETs skills

The challenge: educational institutions often focus on theoretical knowledge, while employers require a combination of both in-depth theoretical knowledge and a good understanding of the basic characteristics of specific application areas.

Several specific measures can be proposed in order to tackle the abovementioned challenge:

- Encouragement or the consortium to include industrial partners from the relevant application areas;
- Encouragement for the above mentioned industrial partners to provide skills development to other consortium members on the specifics of the application area they work with (e.g. key challenges, technical and market trends, target customers, encountered technical limitations etc.);
- Encouragement for the consortium to develop an eco-system in which academic and industrial consortium partners would be allowed/encouraged to:
  - visit each other's facilities and use each other's equipment (especially between partners with a fundamental knowledge of KETs and partners working in a specific application area),
  - jointly work on the solutions in one physical space on a regular basis,
  - maximise the use of virtual collaboration tools (virtual meetings, phone communication, emails etc.) whenever physical collaboration is not immediately possible.
- Encouragement for the consortium to ensure customer/end-user engagement already from the beginning of the project. By this, the consortium partners can obtain direct information on the exact current and future needs of end-users, expected market developments, key challenges etc. This information is reported to be of vital importance for the commercialisation trajectory of the development in question.

The abovementioned measures would ensure a balance of both theoretical and practical knowledge within the consortium, with an efficient exchange of different types of knowledge among the consortium partners, and application of this combined knowledge to specific practical solutions.

Keeping KETs skills up-to-date (part 1: students)

The challenge: students often have to work with the software and equipment that are already outdated, without having access to the state-of-the-art developments, and thus entering the labour market with knowledge and skills that are already out-of-date.

Several specific measures can be proposed in order to tackle the abovementioned challenge:

- Encouragement for consortium members to engage students in project activities, e.g. in a form of traineeships;

- Encouragement for (industrial) consortium partners to provide involved students with an introductory skills development familiarising them with the latest equipment, latest market trends and other practical developments in the field (these industrial partners would need to provide students with access to their skills development facilities). State-of-the art equipment can be located both within companies, but also at prominent research institutes;
- In order to ensure that education does not lag behind industry developments, the skills of educators need to be constantly updated, for example, by arranging exchanges of them with the industry. The educational personnel should be sent to companies to get insights into the latest developments, while people from companies should regularly teach in the classroom.
  - Similarly to students, consortium partners could be asked to engage educators in the project, with a bilateral knowledge exchange (i.e. educators would get the latest insights from the field while also sharing/applying the relevant theoretical knowledge and skills to the needs of the project).

The abovementioned measures would ensure the engagement of students and educators into the state-of-the-art development trajectories, thereby exposing them to up-to-date equipment, real-life challenges and practical solutions. Such approach would considerably advance the quality of the future KETs labour force.

Keeping KETs skills up-to-date (part 2: current KETs workers)

The challenge: after entering the labour market, all specialists in the field of KETs need regular retraining and continuous professional development; at the same time, companies, particularly SMEs, find it challenging to provide such skills development.

Companies, and particularly SMEs, would benefit from the provision by educational institutions of short intensive courses on specific technical areas, with timing and duration being aligned with company needs. That, in turn, would require improved funding mechanisms for educational institutions to make such courses possible.

At the same time, while the majority of the skills development work is done by the educational institutions, some of KETs skills still need to be trained by companies themselves. Such skills include, for example, specialised equipment handling skills and some other narrow technical aspects which are too specific for the curricula of educational institutions. Consequently, companies need to be willing and capable to ensure such skills development.

Several specific measures can be proposed in order to tackle the abovementioned challenge:

- Encouragement for consortium members to embed skills development (of both industry and academic team members) in project activities in order to ensure the highest level of required skills for achieving project objectives:
  - Particular attention/priority would need to be given to the needs of SMEs.
  - The skills development would need to be performed in the most critical area(s) of expertise needed for the implementation of the project.
  - A combination of both technical and non-technical skills development would be highly beneficial.
  - The skills development and implementation plan would need to form part of the application (different options including in-house and internal skills development would need to be allowed depending on the context).
- Launching calls supporting collective organisation of skills development programs and apprenticeships in specific areas of KETs:
  - In order to save costs and solve organisational capacity issues, skills development programs and apprenticeships could be organised by companies collectively. Groups of companies could join their forces to offer in-company skills development programs to their workers that would result in certificates that are recognised throughout the industry.
  - The benefit for the worker is that his/her investment in education and skills remains recognised even when he/she leaves the company.
  - The benefits for the companies besides cost savings are that workers are more inclined to invest time and energy in up-skilling that is recognised throughout the industry, and that the quality of their talent pool increases.
- Launching a pan-European project to collect and disseminate good practices in the field of collective skills development programs and apprenticeships:

- Some good practices already exist in this area (e.g. German 'Rhineland' model of skills generation). The adoption of this practice should be continued, and good practice examples should be replicated on a massive scale.

The abovementioned measures would contribute into continuous professional development of engaged KETs workers and thus lead to a higher quality of the current KETs labour force. It would particularly enable SMEs to participate in the relevant skills development.

Facilitating multidisciplinarity

The challenge: KETs often need people who are trained in various disciplines simultaneously and can work 'on the crossroads' of those disciplines.

Several specific measures can be proposed in order to tackle the abovementioned challenge:

- Encouragement for consortium members to build a multidisciplinary team of people coming from various technical and non-technical backgrounds, including specific application areas;
- Encouragement for the consortium to provide an introductory skills development on each of the involved domains in order to familiarise each of the key experts with the main insights into the specificities of other domains. [However, without prior exposure of a certain expert to another domain, it usually requires at least a year of intensive communication between experts from different fields before they are able to understand each other's context at the level leading to added value creation.]
- Encouragement for the consortium to develop an eco-system in which team members from different backgrounds would be allowed/encouraged to:
  - visit each other's facilities and, whenever necessary, use each other's equipment (especially between partners with a fundamental knowledge of KETs and partners working in a specific application area),
  - jointly work on the solutions in one physical space on a regular basis,
  - maximise the use of virtual collaboration tools (virtual meetings, phone communication, emails etc.) whenever physical collaboration is not immediately possible.

The notion of multidisciplinarity in KETs goes beyond summing up diverse knowledge and skills of individual team members. Facilitating multidisciplinarity implies developing and using a collective knowledge base, collectively exchanging that knowledge and developing new knowledge together.

Ensuring end-user engagement

The challenge: successful NMBP innovations heavily rely on an active involvement of end-users from the very beginning of their innovation trajectory and throughout the whole innovation 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 ideas and feedback, work on the improvement of a certain technology or production process);
- direct contacts with end-users at company premises, conferences, fairs and/or other events;
- interaction with a broader community by means of web blogs and emails;
- Engagement in open source approach (although this measure is not always applicable; an option is to share with public domain only some elements of technology/solutions, protecting the rest in the form of IP or trade secrets).

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 if that information is taken on board, the likelihood of commercial success considerably increases. Consequently, interaction with end-users should be encouraged within 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 and business plan. It should also be part of the proposal assessment.

3.2. Thematic area 2: Mobility

In this sub-section, we present the topics aiming to tackle the issues within thematic area 2, namely Mobility.

Supporting mobility between KETs

The challenge: due to a high complexity of KETs, a single person needs to have a strong expertise in one specific KET, and then a good understanding of another KET; achieving this balance, however, is reported by employers to be a challenge.

Several specific measures can be proposed in order to tackle the abovementioned challenge:

- Launching calls with a multi-KET orientation: it has been demonstrated that the most innovative products incorporate not a single KET but several KETs simultaneously, a so called multi-KETs approach covering the spectrum of multiple KETs. Such an approach enables common solutions and actions, each of which can then achieve a more significant critical mass, effectiveness, visibility and impact[25].
- Encouragement for the consortium to have a team of relevant experts from different KETs;
- Encouragement for the abovementioned experts to provide skills development to other consortium members on the relevant specifics of the KET area they work with (e.g. key challenges, technical and market trends, target customers, encountered technical limitations etc.). Such skills development would need to be provided by the representatives of all KETs involved in the project;
- Encouragement for the consortium to develop an eco-system in which experts from different KETs would be allowed/encouraged to:
  - visit each other's facilities,
  - jointly work on the solutions in one physical space on a regular basis,
  - maximise the use of virtual collaboration tools (virtual meetings, phone communication, emails etc.) whenever physical collaboration is not immediately possible.

The abovementioned measures would ensure bringing experts from different KETs together, thereby exposing experts from one KET domain to the specificities of another KET domain and thus enabling them to better apply their core expertise to the needs of another field. That, in turn, would lead to a more efficient development of common solutions and actions, with a more significant critical mass, effectiveness, visibility and impact.

Supporting mobility to different application areas

The challenge: KETs commercialisation trajectories heavily rely on knowledge and skills from literally every field of life; achieving this balance of skills in KETs workers, however, proves to be a challenge for employers.

Several specific measures can be proposed in order to tackle the abovementioned challenge (these measures are similar to the ones proposed for topic 1.1 "Enhancing practical orientation of technical KETs skills"):

- Encouragement for the consortium to include industrial partners from the relevant application areas;
- Encouragement for the abovementioned industrial partners to provide skills development to other consortium members on the specifics of the application area they work with (e.g. key challenges, technical and market trends, target customers, encountered technical limitations etc.);
- Encouragement for the consortium to develop an eco-system in which consortium partners working in specific KETs and the ones working in specific application areas would be allowed/encouraged to:
  - visit each other's facilities and, whenever relevant, use each other's equipment,
  - jointly work on the solutions in one physical space on a regular basis,
  - maximise the use of virtual collaboration tools (virtual meetings, phone communication, emails etc.) whenever physical collaboration is not immediately possible.
- Encouragement for the consortium to ensure customer/end-user engagement already from the beginning of the project. By this, the consortium members can obtain direct information on the exact current and future needs of end-users, expected market developments, key challenges

[25] Report of High-Level Expert Group on Key Enabling Technologies, Final Report, June 2011

etc. This information is reported to be of vital importance for the commercialisation trajectory of the development in question.

The abovementioned measures would ensure a balance of both core KETs-related knowledge and practical/application-related knowledge within the consortium, with an efficient exchange of different types of knowledge among the consortium partners, and application of this combined knowledge to specific practical solutions.

Supporting mobility along the value chain

The challenge: people working on KETs commercialisation trajectories typically need to be engaged in several parts of the value chain simultaneously (e.g. research and demonstration & piloting; research and manufacturing); achieving this balance of skills in KETs workers, however, proves to be a challenge for employers.

Several specific measures can be proposed in order to tackle the abovementioned challenge:

- Encouragement for the consortium to include partners covering closer-to-market activities (at least up to TRL 6; including prototyping, testing, demonstration and validation; but preferably covering the whole commercialisation trajectory from research to manufacturing);
- Already at the proposal stage, the consortia should be encouraged to address the issues of the exploitation and market take-up of innovative solutions;
- Encouragement for the representatives of different parts of the value chain to provide skills development to other consortium members on the specifics of the phase they work on (e.g. key challenges, encountered technical limitations etc.);
- Encouragement for the consortium to develop an eco-system in which representatives of different parts of the value chain would be allowed/encouraged to:
  - visit each other's facilities and, whenever relevant, use each other's equipment,
  - (from the very beginning of the project) jointly work on the solutions in one physical space on a regular basis,
  - maximise the use of virtual collaboration tools (virtual meetings, phone communication, emails etc.) whenever physical collaboration is not immediately possible.

The abovementioned measures would ensure a balance of knowledge and skills from the whole commercialisation trajectory, with an efficient exchange of different types of knowledge among the consortium partners, and application of this combined knowledge to specific practical solutions. This approach naturally facilitates the development of a close interrelationship of required skills among different steps of the value chain, with multiple connections and significant overlaps.

Supporting geographical mobility

The challenge: while geographical mobility provides a number of considerable benefits for the advancement of knowledge and skills, companies often face resistance among employees to engage in this type of mobility

Several specific measures can be proposed in order to tackle the abovementioned challenge:

- Encouragement for the consortium to include partners from different geographical regions;
- Encouragement for the consortium to develop an eco-system in which representatives of different geographical regions would be allowed/encouraged to:
- visit each other's facilities and, whenever relevant, use each other's equipment,
- (from the very beginning of the project) jointly work on the solutions in one physical space on a regular basis; both long-term (project length) and short-term exchanges need to be stimulated;
- Already at the proposal stage, the consortia should be encouraged to address the issues of geographical mobility of project experts.

The abovementioned measures would ensure a balance of different geographical backgrounds within the consortium, with an efficient exchange of different types of knowledge among the consortium partners, and application of this combined knowledge to specific practical solutions. This approach encourages the consortia to bring different knowledge and cultures together, have an open-mind experience and build around different points of view, thereby opening up previously unknown horizons.

Supporting mobility between academia and industry

For an overview of the relevant measures, the reader is advised to consult points made in section 2.1.

3.3. Thematic area 3: Entrepreneurial skills

In this sub-section, we present the topics aiming to tackle the issues within thematic area 3, namely Entrepreneurial skills.

Enhancing entrepreneurial orientation of Horizon 2020 projects

The challenge: entrepreneurial skills can typically be mastered well if the person possesses a so called 'innate entrepreneurial spirit'; nevertheless, some entrepreneurial skills can be taught, and there is a need to offer KETs workers the relevant opportunities.

Several specific measures can be proposed in order to tackle the abovementioned challenge:

- Encouragement for the consortium to include experts with an entrepreneurial background (i.e. strong knowledge of and experience with the commercialisation trajectories of high-tech innovations, including financial, marketing and legal issues);
- Encouragement for the abovementioned experts to provide other project members with a skills development on the key entrepreneurial aspects relevant to the project in question (i.e., market analysis, key legal aspects, key financial aspects etc.);
- Already at the proposal stage, encouragement for the consortium to elaborate on their approach towards addressing the key entrepreneurial aspects including the identification of potential application areas, analysis of market trends and customer needs, competition analysis, market penetration strategies etc.
- Encouragement for the consortium to develop an eco-system in which experienced entrepreneurs and other consortium partners would be allowed/encouraged to:
  - jointly work on the solutions in one physical space on a regular basis,
  - maximise the use of virtual collaboration tools (virtual meetings, phone communication, emails etc.) whenever physical collaboration is not immediately possible.

The abovementioned measures would ensure a solid presence of entrepreneurial knowledge within the consortium, with an efficient exchange of relevant knowledge among the consortium partners, and application of this combined knowledge to specific practical solutions.

Supporting entrepreneurial skills development for SMEs

The challenge: companies, particularly SMEs, find it challenging to provide entrepreneurial skills development due to financial and organisational constraints.

Specific measures can be proposed in order to tackle the abovementioned challenge:

- Encouragement for the consortium to include SMEs and ensure the involvement of SME project members into activities listed in section 3.1 of this report.

This measure would ensure the involvement of SMEs into the development and advancement of entrepreneurial skills in KETs by means of exchange of relevant knowledge among the consortium partners, and application of this combined knowledge to specific practical solutions.

Enhancing exposure of students and KETs workers to successful entrepreneurs

The challenge: students and KETs workers rarely get an opportunity to meet and learn from successful entrepreneurs; this leads to a low awareness about the entrepreneurial opportunities of KETs and thus jeopardises the commercialisation potential of KETs-related ideas.

Several specific measures can be proposed in order to tackle the abovementioned challenge:

- Launching a call to organise a European conference on entrepreneurship in KETs, where students and/or current KETs workers would be offered an opportunity to meet successful KETs entrepreneurs/entrepreneurship experts and engage in interactive discussions;
- Launching a call to organise a European entrepreneurship boot camp for KETs, where students and/or current KETs workers would be offered an opportunity to work on their ideas together with successful KETs entrepreneurs/entrepreneurship experts (i.e. to receive their regular feedback and close guidance). This boot camp could combine working in one physical space with

entrepreneurship experts for a certain period of time, with periodical physical meetings and intensive virtual collaboration.

The abovementioned measures would increase the exposure of students and KETs workers to successful entrepreneurs/entrepreneurship experts, leading to a higher awareness about the entrepreneurial opportunities of KETs and thus better use of the commercialisation potential of KETs-related ideas.

3.4. Thematic area 4: HR management skills

In this sub-section, we present the topics aiming to tackle the issues within thematic area 4, HR management skills.

Increasing the awareness of society about KETs as a field to work in

The challenge: critical career decisions are being made already more than a decade before a student enters the workforce; however, at that point, children are often not familiar with the development opportunities within KETs. Furthermore, KETs are even less popular among girls, and with no sufficient attention to this group at early age, half of the potential future labour market is likely to be overlooked.

Several specific measures can be proposed in order to tackle the abovementioned challenges:

- Launching a call (multiple calls) aiming to support the development of educational kits for KETs:
  - Educational kits equipping teachers with experimental KETs-related material need to be disseminated to schools across Europe with a supporting didactic framework. The latter refers to video clips, PowerPoint slides, instructions for experiments etc. These kits should be committed to creating safe, engaging, affordable hands-on learning tools, curriculum and resources that inspire and support teaching and learning about the essence of different KETs in the classroom.
  - Once developed, kits should be translated into other languages and disseminated among teachers who are motivated to use the kit in their classroom to excite children about science in general and specific KETs in particular.
- Launching a call (multiple calls) aiming to support the development of KETs-related MOOCs:
  - Massive Open On-Line Courses (MOOCs) could be another way of attracting young scientists and engineers into KETs-related education. MOOCs represent online courses aimed at unlimited participation and open access via Internet. MOOCs typically combine traditional course materials such as videos, readings and exercises, with interactive user forums that help build a community for students, professors and teaching assistants. MOOCs are a relatively recent phenomenon in distance education that began to massively emerge in 2012[26].
  - The key benefits related to MOOCs include appropriateness for any setting that has connectivity (Web or Wi-Fi), escape from time zones and physical boundaries, informal setting, easier to cross disciplines and institutional barriers, lower barriers to student entry, enhanced personal learning environment and improved lifelong learning skills[27].
- Launching a call aiming to develop a targeted communication strategy on KETs as a field to work in:
  - A targeted communication strategy needs to be developed, including a careful selection of media to reach out to the targeted publics. In order to achieve large-scale effects, mainstream media should be employed as much as possible (e.g. TV, non-scientific newspapers & magazines). Additionally, social media and popular Internet websites could be mobilised to effectively reach the targeted audience. The latter goes beyond young people, and also includes parents, teachers and society in general.
  - A special targeted communication strategy on KETs needs to be developed for girls, targeting also their parents and teachers, and aiming at increasing their awareness of the

[26] Pappano L. "The Year of the MOOC", The New York Times, 2 November 2012

[27] "Benefits and Challenges of a MOOC", MoocGuide, 7 July 2011, available at: http://moocguide.wikispaces.com/2.+Benefits+and+challenges+of+a+MOOC

opportunities within KETs for girls. This measure is needed to overcome the issue of gender imbalance in STEM domains in general and KETs in particular.

The abovementioned measures would contribute towards raising awareness on KETs as a field to work in in the society in general, with a particular focus on children, teachers and parents, and specifically addressing the issues of gender balance in KETs. At this point, hardly any measures are being applied in Europe to tackle the abovementioned challenge on a massive scale. Supporting these measures within the Horizon 2020 Programme would address the issue of common European interest.

Improving the image of KETs as a field to work in

The challenge: the weak image of KETs is reported to be the most important obstacle encountered by companies when trying to attract people.

The following specific measures can be proposed in order to tackle the abovementioned challenge:

- Launching a call (multiple calls) to support the development of dedicated promotional campaigns aiming to improve the image of KETs in the society:
  - These campaigns should be aimed at 'rebranding' of KETs as an exciting and prestigious field to work in, with an opportunity to solve the grand societal challenges. Examples of means to achieve it could be reality shows, movies, TV series, commercials, computer games where KETs professionals are presented as somebody to look up to.
  - Besides, role model strategy should be actively mobilised, aiming to showcase successful people working in KETs, at all levels, starting from talented children already active in this domain (e.g. the winners of Google Science Fair[28]).
  - A special targeted communication strategy on KETs image needs to be developed for girls, targeting also their parents and teachers, and aiming at increasing the attractiveness of KETs for girls. This measure is needed to overcome the issue of gender imbalance in STEM domains in general and KETs in particular.

The abovementioned measures would contribute towards creating a better image of KETs as a field to work in, in the society in general, with a particular focus on children, teachers and parents, and specifically addressing the issues of gender balance in KETs. At this point, hardly any measures are being applied in Europe to tackle the abovementioned challenge on a massive scale. Supporting these measures within the Horizon 2020 Programme would address the issue of common European interest.

[28] A global online competition open to students from 13 to 18; for more information, see https://www.googlesciencefair.com

4. Recommendations for other actions and policies

This chapter presents recommendations on other relevant measures at the level of Research & Innovation policy that could help tackle the skills imbalances in KETs. The outputs provided in this chapter refer to suggestions for other actions, including further studies (investigations and conceptual activities), as well as other policy measures. We focus on policy measures where European dimension is particularly important; however, we also address the role of stakeholders at other levels, including national and regional policy levels, as well as educators, and industry (and particularly SMEs).

Each topic in this chapter reflects a specific objective within each of the four thematic areas covered by the study. Within each topic, we formulate a specific challenge, and then elaborate on a proposed scope of measures and expected impact of these measures.

4.1. Thematic area 1: Technical skills

In this sub-section, we present the topics aiming to tackle the issues within thematic area 1, namely Technical skills.

Enhancing practical orientation of technical KETs skills

The challenge: educational institutions often focus on theoretical knowledge, while employers require a combination of both in-depth theoretical knowledge and hands-on practical skills.

The following measures can be proposed in order to tackle the abovementioned challenge:

- EU-level support to initiatives that allow students to gain experience in labs (both academic and industry labs) in order to ensure their exposure to lab environment already during their studies (a sample good practice already exists in Grenoble and is supported at the Rhône-Alpes region; similar initiatives need to be supported also at the EU level).
- EU-level support to initiatives that stimulate direct involvement of industry in the education process for vocational education, Bachelor and Master students (e.g. involvement of industry in the development of curricula, teaching/part-time positions of industry representatives in academia, field visits of students to industry, traineeship programmes for students at companies etc.).
  - Suggestion for a study: As an initial step, an exploratory study on the (potential) motivation of industry to engage in such activities needs to be conducted. During this study, good practice examples would need to be collected together with inputs on the key challenges and constraints for industry to engage in the educational process, and the ways to overcome these constraints. These inputs could serve as a knowledge base for the development of effective and targeted policy actions and/or programmes at the EU level.
- The need to adjust the curricula of educational institutions (both VET and universities) to industry requirements should be promoted in a top-down way (by EU and national policy makers), accompanied by adjustments in regulation to provide the educational institutions with sufficient flexibility to change the curriculum and by providing educators with additional financial means to introduce change. Member States need to offer favourable conditions for the (top) educational institutions to interact with industry.
- The European Commission should continue offering funding support for cooperation projects between business, education and skills development institutions to try out new approaches (currently offered by DG EAC Erasmus+ programme[29]). Business, education and skills development institutions need to be better informed about the existence of this support.
- Suggestion for a study: developing KETs Skills Observatory. KETs skills is an emerging field of study, with relatively limited research carried out so far on the main workforce flows in KETs on a yearly basis. A dedicated "KETs Skills Observatory" could be developed to monitor how supply and demand of KETs skills changes in time. The Observatory would allow for continuous tracing of the main workforce flows in KETs, as well as for monitoring changes in the gap in KETs skills from both the qualitative and quantitative perspectives.
  - The Observatory could systemise both the actual developments on the KETs skills market and the forecasts for the coming years.

[29] https://eacea.ec.europa.eu/erasmus-plus_en

- Furthermore, besides mapping KETs skills-related data, the Observatory could serve as a platform for further engagement of KETs community in developing policy recommendations. The latter refer to concrete policy actions to foster, support, and scale up KETs skills in Europe.

The abovementioned measures would ensure a better balance of both theoretical and practical knowledge in students/graduates, with the exposure of the latter to practical challenges and required practical skills already during their studies. The KETs Skills Observatory would provide policy makers with a powerful knowledge base for designing effective programmes and measures with an aim to fully realise KETs growth potential in Europe.

Keeping KETs skills up-to-date (part 1: students)

The challenge: students often have to work with software and equipment that are already outdated, without having access to the state-of-the-art developments, and thus entering the labour market with knowledge and skills that are already out-of-date.

The following measures can be proposed in order to tackle the abovementioned challenge:

- EU-level support to initiatives that facilitate updating the skills of teachers, for example, by arranging exchanges of them with industrial actors from one of the KETs domains (i.e. pan-European and national teacher exchange schemes with industry).
- EU-level support to initiatives that facilitate innovation in teaching. Educators need to be stimulated to try out new approaches and continuously update the materials they teach. Educational institutions and teachers/professors should be rewarded for introducing innovative approaches. These aspects need to be embedded in the assessment schemes for both organisations and individuals (e.g. in case of educational institutions, additional funding could be granted to the ones with the most up-to-date curricula; in case of individuals, reward system should take this criterion into account). As long as university professors get rewarded mainly for the number of papers they publish, there is hardly any stimulus for them to introduce any change in the educational process.
- EU-level support to initiatives that facilitate access of students to state-of-the-art equipment used within the KETs domain. Such equipment could be located both within KETs companies, but also at prominent research institutes focussed on KETs (which are limited in number). It could be beneficial to have a few academic centres of excellence in Europe regularly receiving students from other technical universities and developing their skills on how to use the latest equipment. However, since KETs equipment is highly expensive, it would require significant investments into these centres of excellence and it may need to be linked with other EU programmes, e.g. the ones related to infrastructure.
- Introducing European Bachelor/Master programmes where students would be allowed to spend some time at one of the abovementioned academic centres of excellence as a compulsory part of their KETs education.

The abovementioned measures would ensure a better access of students to the state-of-the-art developments, thereby increasing the added value and relevance of knowledge their acquire during their studies and raising the quality of the (future) KETs labour force.

Keeping KETs skills up-to-date (part 2: current KETs workers)

The challenge: after entering the labour market, all specialists in the field of KETs need regular retraining and continuous professional development; at the same time, companies, particularly SMEs, find it challenging to provide such skills development.

The following measures can be proposed in order to tackle the abovementioned challenge:

- EU-level support to initiatives that facilitate on-the-job skills development for SMEs (pan-European and national schemes (partially) funding such activities).
- Promotion of the idea of collective organisation of skills development activities and traineeship programs for companies. In order to save costs and solve organisational capacity issues, skills development programs and apprenticeships could be organised by companies collectively. Groups of companies could join their forces to offer in-company skills development programs to their workers that would result in certificates that are recognised throughout the industry. The benefit for the worker is that his/her investment in education and skills remains recognised even when he/she leaves the company. The benefits for the companies besides cost savings are that workers are more inclined to invest time and energy in up-skilling that is recognised throughout the industry, and that the quality of their talent pool increases.

The abovementioned measures would support regular retraining and continuous professional development of KETs workers, particularly at SMEs, a group of companies that finds it specifically challenging.

Facilitating multidisciplinarity

The challenge: KETs often need people who are trained in various disciplines simultaneously and can work 'on the crossroads' of those disciplines.

The following measures can be proposed in order to tackle the abovementioned challenge:

- EU-level and national support to the concept of 'dual learning'[30]. Dual learning implies combining education with work experience, thereby acquiring experience in an actual (manufacturing) environment before entering the labour market. Since industry works in a multidisciplinary way, students will get exposed to this notion already in the course of their education.
- EU-level and national support to activities that promote working in different laboratories as part of training for engineers. Specifically, post docs could be stimulated to work in a scientific domain close to their initial background, but still being a different area (in order to diversify their knowledge and skills).

The abovementioned measures would support new ways of providing education and skills development, and specifically the ones going beyond the traditional 'silos' approach and facilitating the identification of linkages between previously unconnected fields and diversity of profiles of team members.

4.2. Thematic area 2: Mobility

In this sub-section, we present the topics aiming to tackle the issues within thematic area 2, namely Mobility.

Supporting geographical mobility

The challenge: while geographical mobility provides a number of considerable benefits for the advancement of knowledge and skills, companies often face resistance among employees to engage in this type of mobility.

The following measures can be proposed in order to tackle the abovementioned challenge:

- Paying EU- and national-level attention to the unification of social measures including certificates and diplomas. Social security measures need to support mobility too (e.g. transferable pension plans). These matters are not harmonised at the moment, which makes geographical mobility less attractive to KETs workers.
- Advancing EU and national policies that help attracting non-EU talent. Some of the EU MS already have favourable conditions for highly-skilled non-EU workers (e.g. Netherlands). However, to obtain the status of a highly skilled immigrant, a certain minimum salary is required that in some cases is not affordable to companies. This especially holds for non-EU talent with a postdoc education, but with limited working experience.

The abovementioned measures would remove some of the key existing barriers to geographical mobility and thereby allow more KETs workers to advance their knowledge and skills by means of an international exchange.

Supporting mobility between academia and industry

[30] Also known as alternate education (e.g. 6 months in classrooms and 6 months in industry). Research shows that students which followed such alternate education have better job opportunities when entering the market. The EU already has a programme for companies to attract students: Marie Curie program. A similar programme could be developed specifically for KETs, for example, at a Master level. There is a need for a scheme in which companies are rewarded for co-educating a student, by providing them a guarantee that the trained student will eventually work for the respective company for a certain period of time.

The challenge: mobility between academia and industry is reported by the stakeholders to be a vital way to advance the level of KETs skills; at the same time, the number of policy initiatives supporting this type of mobility on a massive scale is still limited.

The following measure can be proposed in order to tackle the abovementioned challenge:

- EU- and national-level measures that support developing open eco-systems where academia and industry could collaborate together on a continuous and sustainable basis (not just on a project basis). Within such eco-systems, academic and industrial consortium partners need to be allowed/encouraged to:
  - visit each other's facilities and use each other's equipment (especially between partners with a fundamental knowledge of KETs and partners working in a specific application area),
  - jointly work on the solutions in one physical space on a regular basis.

The abovementioned measure would facilitate an efficient exchange of different types of knowledge and skills between academic and industrial parties, and the application of this combined knowledge to specific practical solutions.

4.3. Thematic area 3: Entrepreneurial skills

In this sub-section, we present the topics aiming to tackle the issues within thematic area 3, namely entrepreneurial skills.

Enhancing entrepreneurial orientation of KETs-related education

The challenge: while stakeholders increasingly report the need to train entrepreneurial skills in future KETs workers already during the studies, educational institutions in general keep focussing on developing technical skills, with little or no attention to entrepreneurial skills.

The following measure can be proposed in order to tackle the abovementioned challenge:

- EU- and national support to the measures developing entrepreneurial adaptability. By entrepreneurial adaptability here one should understand being open to change (positive or negative) and the ability to accept, prepare for and handle change in the entrepreneurial environment. A rapidly changing landscape of KETs requires constant adaptation to new developments. Consequently, students need to be taught how to stay flexible and be prepared for constant change, be it organisational, technological, social or other type of change. Entrepreneurial adaptability can be introduced at the level of secondary school and be particularly stimulated during the tertiary education, and as a central part of company's working culture.

This measure would allow to develop basic entrepreneurial skills (in a broader sense) which could subsequently be advanced at later stages of education by means of more targeted entrepreneurship skills development.

Enhancing exposure of students and KETs workers to successful entrepreneurs

See section 3.3. The proposed measures can be implemented using different schemes (i.e. through Horizon 2020 or/and through other policy initiatives).

4.4. Thematic area 4: HR management skills

In this sub-section, we present the topics aiming to tackle the issues within thematic area 4, HR management skills

Increasing the awareness of society about KETs as a field to work in

See the points made in section 3.4. The proposed measures can be implemented using different schemes (i.e. through Horizon 2020 or/and through other policy initiatives).

Improving the image of KETs as a field to work in

See the points made in section 3.4. The proposed measures can be implemented using different schemes (i.e. through Horizon 2020 or/and through other policy initiatives).

Advancing HR skills for academic personnel

The challenge: stakeholders often report the need to provide university HR personnel with additional skills development in order to advance their skills for finding and selecting the right people.

The following measure can be proposed in order to tackle the abovementioned challenge:

- EU and national-level support for advancing the skills of HR personnel in academia, by, for example, offering targeted skills development on identifying and targeting potential talent that may excel in academic work within the KETs domain.

The abovementioned measure would allow to further professionalise the skills portfolio management in European universities.

5. CONCLUSIONS

Based on this study, that aims to provide the Commission with the analysis and recommendations on skills in the NMBP areas, aiming to tackle the growing skills imbalances, both from the Horizon 2020 and from policy perspectives, several conclusions can be drawn related to how skills-related issues can be addresses in research and innovation activities, especially within the area of NMBP. Firstly, engagement across the different types of members of a research group, consortium or community can benefit skills development within such a research or innovation consortium. Secondly, engagement between a research group or consortium and their stakeholders is an important avenue for addressing skills issues within a research project. Thirdly, involvement of industrial actors in the education system can address skills issues related to the combination of theoretical and practical knowledge. Finally, engagement with successful KETs entrepreneurs can address entrepreneurial skills both among current KETs workers and among prospective KETs workers.

An important avenue for improvement relates to engagement and skills development within a research or innovation consortium across the different types of its members. Consortium members with an industrial focus can enhance the understanding of the consortium on the application area in which they work. Consortium members that work on different parts of the value chain can enhance the understanding of the consortium on the specific aspects and key challenges important to their type of work. Consortium members that focus heavily on entrepreneurial activities can enhance the understanding of the consortium on entrepreneurial considerations and what they are based on, such as market analyses and financial aspects.

Also, engagement between a research group or consortium and their stakeholders is an important route towards addressing skills issues within a research project. End-user engagement in the early phase of a research project will specifically address and develop the skills needed to apply combined technical knowledge to specific practical solutions. Also, engaging technology students in research project activities will address and develop skills required among graduates to work with the latest, state-of-the-art equipment and tools, and prepares them for the most recent practical developments in their technology field.

Focus should also be placed on aspects that pertain to the education system. Industrial actors can be involved more in the education process, to help achieve a combination in technology teaching of both in-depth theoretical knowledge and hands-on practical skills. Consequently, by arranging exchanges with these industrial actors, the level of technological understanding among teachers may be improved, especially for teachers at the primary, secondary and vocational level. Also, harmonisation across different types of certificates and diplomas may help address the perception of a limited supply of skills.

Similarly, the notion of entrepreneurial skills development is closely related to the education system and to engagement with successful KETs entrepreneurs both by students and by current KETs workers. Opportunities to meet successful entrepreneurs in KETs and to work with them on shared ideas can generate higher awareness on entrepreneurial opportunities within KETs and can increase the entrepreneurial skills of current and prospective KETs workers. In the medium term, the effects of such initiatives can be enhanced by training entrepreneurial skills (such as adaptability and anticipating organisational, technological and social change) already at secondary educational level.

These conclusions on how skills-related issues can be addresses in research and innovation activities are relevant to the NMBP area and to KET domains in general. Moreover, it can be postulated that these conclusions are relevant to skills issues across domains outside of KETs, addressing all STEM areas. Indeed, interaction across the different types of members of a research community with an aim to learn from one-another and early-stage communication between a research group or consortium and their stakeholders is important for all technology domains, not only those related to KETs. However, as has been argued in this study, KETs imply a need for multidisciplinary collaboration, cross-road thinking and innovative system-level approaches within an environment characterised by high-speed technological change and by opportunities for deep societal impact. As such, the conclusions presented in this report should be considered especially relevant to KETs and to the field of NMBP in particular.

ANNEX A: GOOD PRACTICES FOSTERING THE DEVELOPMENT OF TECHNICAL KETS SKILLS

This Annex describes good practices fostering the development of KETs skills in Germany, the United Kingdom, Sweden, Italy and Estonia. For each country, a brief discussion of the RDI policy is presented and the extent to which it focuses on specific KETs. A concise overview of KETs-related policy initiatives is presented, followed by a concluding paragraph on the skills approach of the country and the extent to which it focuses on KETs skills.

A.1. Germany

RDI policy in Germany is deployed through various strategies and initiatives that aim to create the right framework conditions to allow the German economy to generate and sustain scientific progress, technological development and economic growth. It specifically focuses on the expansion of higher education opportunities and structurally boosting university research, on introducing and intensifying competition between universities, on networking and interchange among researchers and innovators (both domestically and internationally), and on academia-industry cooperation[31].

The German RDI policy landscape does not have a specific focus on KETs. Oftentimes KETs-relevant policies are embedded in broader policy programmes on the wider RDI theme. Yet some programmes focus on specific individual KETs, prioritising photonics, nanotechnology, and industrial biotechnology.

The KETs-related policy initiatives in Germany include[32]:

- ***Innovation alliances*** (nanotechnology, micro- and nanoelectronics, photonics, advanced manufacturing technologies): the objective is to support and fund strategic cooperation between industry and public research in key technology areas that demand a large amount of resources and that have a long time horizon;
- ***Industry 4.0*** (advanced manufacturing): the objective is to support German industry to grasp the opportunity to actively shape the fourth industrial revolution. The aim is to develop completely new business models and tap the considerable potential for optimization in the areas of production and logistics. Other factors include new services in important areas of application – such as the fields of action of mobility, health and climate and energy as identified in the High-Tech Strategy;
- ***Optical Technologies*** (photonics): the objective is to encourage the development of scientific-technical bases, strengthening innovation and competitiveness, and supporting education and retraining;
- ***Photonics Research Germany*** (photonics): the objective is to encourage the development of scientific-technical bases, strengthening innovation and competitiveness, and supporting education and retraining;
- ***Nano Initiative – Action Plan*** (nanotechnology): the objective is to open up potential markets and boost employment prospects in the field of nanotechnology;
- ***Framework Concept for the Production of Tomorrow*** (advanced manufacturing technologies, nano-and microelectronics): the objective is to foster the manufacturing industries of Germany in an ever more dynamic and competitive environment;
- ***Framework Programme: Materials Innovations for Industry and Society (WING)*** (advanced materials / nanotechnology): the objective is to strengthen the innovative power of companies in the materials industry, and to deploy their potential for research and technological development for sustainable development;
- ***Framework programme "Biotechnology – Using and Shaping its Opportunities"*** (industrial biotechnology): the objective is to maintain the high standard of performance in the biotechnology sector in Germany over the coming years;
- ***BioIndustry 2021*** (industrial biotechnology): the objective is to further promote industrial biotechnology in a way that has strategic clusters emerge within Germany;

[31] http://www.research-in-germany.de/en/research-landscape/r-and-d-policy-framework.html

[32] https://webgate.ec.europa.eu/ketsobservatory/sites/default/files/policy/GERMANY.pdf

- ***IGF – Promotion of Joint Industrial Research (including ZUTECH)*** (Advanced manufacturing technologies): the objective is to mitigate structure-related disadvantages of SMEs in R&D activities, by supporting cooperation with institutes of higher education and industry related research institutes;
- ***Central Innovation Programme SME*** (nanotechnology, industrial biotechnology, advanced materials, advanced manufacturing, technologies, photonics, micro- and nanoelectronics): the objective is to promote research and development projects in SMEs through grants;
- ***Dresden Microelectronics Academy*** (microelectronics): the objective is to introduce graduate students and PhD students with high potential to organisations in industry and academia in the Dresden area;
- ***CC-NanoChem centre of excellence*** (Nanotechnology): the objective is to enhance connectivity and cooperation between universities, research centres, small, medium-sized and large enterprises, as well as consultants and venture capitalists.

In general, RDI policy in Germany is characterised by a combined approach to skills, which includes activities that focus specifically on one KET, and which also includes activities that focus on KETs in general, and on skills in general. Typically, these initiatives are driven by government agencies appointed by the federal government, in cooperation with local government and relevant universities.

A.2. The United Kingdom

RDI policy in the United Kingdom is deployed via government support for private sector innovation, direct government action, and public-private sector interaction[33]. Government support focuses on funding blue skies research as well as new discoveries and inventions, improving the interface between higher education institutions and business, and delivering a better environment for commercialising research. Direct government action is taken on public procurement of innovation in a lead-customer role and through the Small Business Research Initiative, and by increasing access to public data and to knowledge created as a result of publicly funded research.

The RDI policy landscape in the United Kingdom does not have a specific focus on KETs. Oftentimes KETs-relevant policies are embedded in broader policy programmes on the wider RDI theme. Yet some programmes focus on specific individual KETs, prioritising micro- and nanoelectronics.

The KETs-related policy initiatives in the United Kingdom include[34]:

- ***Collaborative Research & Development*** (multi-KETs): the objective is to assist the industrial and research communities to work together on R&D projects in strategically important areas of science, engineering and technology, from which successful new products, processes and services can emerge;
- ***Innovation Platforms*** (multi-KETs): the objective is to foster innovation and focus on societal challenges by facilitating dialogue amongst industry, academia and government to align innovation policy and government procurement with market activities;
- ***Knowledge Transfer Networks*** (multi-KETs): the objective is to provide businesses, members of business organisations, and research and technology organisations with the opportunity to improve their information sharing through networking opportunities;
- ***Knowledge Transfer Partnerships*** (multi-KETs): the objective is to increase interactions between on the one hand universities, research organisations and Further Education Colleges, and on the other hand businesses and companies, through the organisation and establishment of apprenticeships that have knowledge transfer of one of their aims;
- ***Micro and Nanotechnology Manufacturing Initiative*** (nanotechnology, micro- and nanoelectronics): the objective is to help UK industry build on the expertise of universities and research organisations in the UK, in order to increase the commercial opportunities in nanotechnology;
- ***Small Business Research Initiative*** (multi-KETs): the objective is to help gain SMEs gain access to R&D opportunities when providing goods and services to the UK government;

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[33] UK Department for Business, Innovation & Skills, 2011, Government innovation and research strategy

[34] https://webgate.ec.europa.eu/ketsobservatory/sites/default/files/policy/United-Kingdom.pdf

- ***UK Strategic Investment Fund*** (multi-KETs): the objective is to support targeted investments in industrial projects of strategic importance, in order to strengthen the UK economy's capacity for innovation, job creation and growth;
- ***IPG Photonics Laboratory*** (photonics): the objective is to teach students photonics, with emphasis on fibres, lasers, and detectors, in order to encourage greater photonics research, given the burgeoning job market in photonics and the University's strength in optics-related sciences;
- ***MIB – Industrial Partnership Awards*** (industrial biotechnology): the objective is to transfer knowledge and to develop graduate and postgraduate personnel for industrial careers. Applications are encouraged from biotechnology small- and medium-sized enterprises;
- ***National Microelectronics Institute*** (Nano- and microelectronics): the objective is to help build and support a strong micro- and nanoelectronics community by acting as a catalyst and facilitator for both commercial and technological development.

In general, RDI policy in the UK is characterised by a combined approach to skills, which typically includes activities that focus on multi-KETs apprenticeships and knowledge sharing, yet that also focuses on skills in general. Initiatives are driven predominantly by government (the department for business, innovation and skills – BIS) and the UK Technology Strategy Board. The skills councils have been decommissioned over the last view years.

A.3. Sweden

RDI policy in Sweden is based on creation of a knowledge base for innovation, development of innovative trade and industry, and the use of innovative public investments and the promotion of innovative people[35]. It focusses particularly on strategic programmes for key industries, a better structure for seed financing, focused R&D investments in engineering, life sciences and natural sciences, and measures to strengthen the industrial institutes, as well as the encouragement of innovation activities within SMEs.

This RDI policy landscape is not particularly focused on KETs, and where it is, it focusses on nanotechnology, industrial biotechnology, advanced manufacturing, and advanced materials. Policy initiatives are not so much geared to skills, and they are focused more on bridging the gap between R&D and industrialisation.

The KETs-related policy initiatives in Sweden include[36]:

- ***Green Nano*** (nanotechnology): the objective is to support the development of new or improved products and solutions that by combining nanotechnology and environmental technology have better performance and which are less harmful to the environment than the products they intend to replace;
- ***Industrial Biotechnology*** (industrial biotechnology): the objective is to stimulate research and development and the implementation of industrial technologies in various sectors in order to promote more environment-friendly processes linked to economic growth, through funding collaborative research consortia from academia and industry;
- ***ProViking*** (advanced manufacturing): the objective is to support research in product development, manufacturing, and product maintenance, through production academies and virtual graduate programmes in advances manufacturing;
- ***Greenchem – specialty chemicals from renewable resources*** (industrial biotechnology): the objective is to initiate a paradigm shift in the chemical industry, from being based on fossil resources to being based on renewable raw materials for the manufacturing of 'green' chemicals, through demonstration projects and the development of technology roadmaps;
- ***Designed materials including nanomaterials*** (nanotechnology, advanced materials): the objective is to shorten the commercialisation process in the field of advanced materials, especially focussing on the industrialisation phase of the project, by funding projects that aim to uncover the knowledge needed to pilot and demonstrate advanced materials and that aim to build value chains and networks.

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[35] OECD Reviews of Innovation Policy: Sweden 2012, available at http://www.oecd-ilibrary.org/science-and-technology/oecd-reviews-of-innovation-policy-sweden-2012_9789264184893-en

[36] https://webgate.ec.europa.eu/ketsobservatory/sites/default/files/policy/sweden.pdf

Typically, RDI policy in Sweden does not have an articulated approach to skills, yet focuses more on activities that bridge the gap between research and industrialisation. Existing KETs skills initiatives in Sweden also focus on this aspect. These initiatives are initiated at the national level by the Ministry of Education and Science and the Ministry of Industry, Employment and Communications, and are de-centrally implemented by government agencies and triple-helix organisations.

A.4. Italy

The Italian RDI policy landscape is aimed at creating a research and innovation friendly environment, especially for SMEs, improving the human capital base for research and innovation, i.e. to increase the educational attainment and improve the skills of the population, improving funding opportunities for research innovation, especially with respect to SMEs, and at strengthening technology transfer between public research and business and accelerating the transfer of new basic research findings to the market place[37].

Although skills improvement is one of the aims of Italian RDI policy, it does not focus specifically on KETs. Rather, it covers KETs within its broader approach to technological innovation and development.

The KETs-related policy initiatives in Italy include[38]:

- ***Italian technological districts*** (multi-KETs): the objective is to promote the innovation capacity of Italian enterprises, in order to improve the competitiveness of existing export intensive product areas, by revitalising them through R&D activities on product and process innovations based on key enabling technologies;
- ***Flagship projects*** (multi-KETs): the objective is to identify and develop innovation projects of strategic interest, and through funding and policy support build them into flagship projects that attract private sector investment and that serve as best-in-class examples for innovation projects to follow;
- ***FAR industrial support fund*** (multi-KETs): the objective is to finance research projects of consortia of businesses, research centres and science parks, in order to spur industrial research activities that turn research results into new projects or in product prototypes;
- ***RIDITT – Italian network for innovation and technology transfer to SMEs*** (multi-KETs): the objective is to improve the competitiveness of the Italian production system by strengthening and integrating the supply of services for innovation, by promoting knowledge sharing of best practices, encouraging services for innovation and technology enterprises, strengthening innovation networks, improving access to finance, and supporting the internationalisation of innovation centres;
- ***Industry 2015 – Programme for research institutes and private companies*** (multi-KETs): the objective is to develop and improve the Italian industrial system, by taking the opportunities arising from the growth of private demand of highly innovative goods, to improve the capacity of the production system to effectively fit the new needs that characterise an advanced society, through project financing.

In general, ***RDI policy in Italy is characterised by an approach to skills that covers a wide variety of technology domains***, and is not limited or focussed on any specific KET or set of KETs. KETs initiatives are typically geared towards industrial development and knowledge transfer, and are initiated by national and regional government bodies.

A.5. Estonia

RDI policy in Estonia is deployed through a national strategy that aims to enhance the competitive quality and intensity of R&D, to encourage innovative companies to create value to the global economy through internationalisation efforts, and to shape an innovation-friendly society aimed at

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[37] European Commission, 2007, Monitoring and analysis of policies and public financing instruments conducive to higher levels of R&D investments The "POLICY MIX" Project - Country Review Italy

[38] https://webgate.ec.europa.eu/ketsobservatory/sites/default/files/policy/italy.pdf

long term development[39]. Co-financing through EU structural funds are very important to the implementation of these programmes. There are no regional or local priorities in the strategy. The national strategy focuses on ICT, healthcare, and materials and resources[40], through demand-side policies, collaboration networks, support for start-ups, support for applied research, and specialty scholarships[41].

The Estonian RDI policy landscape does not have a specific focus on KETs. Oftentimes KETs-relevant policies are embedded in broader policy programmes on the wider RDI theme. Yet some programmes focus on specific individual KETs, prioritising industrial biotechnology and advanced manufacturing.

The KETs-related policy initiatives in Estonia include[42]:

- ***The centres of excellence of the Estonian science programme*** (industrial biotechnology): the objective is to increase the capability of research and development activities and innovation in Estonian biotechnology, and to create and maintain top qualifications of research and development activities by developing a small number of centres of excellence in the areas considered a priority from the viewpoint of economic growth, such as industrial biotechnology, on which four centres have been established;
- ***Competence centres*** (nanotechnology, industrial biotechnology, advanced manufacturing technologies): the objective is to conduct research in areas of relevance for the product development of the participating companies; the ultimate goal is to develop products and services competitive in the world market through the education of two generations of PhDs with experience with industrial cooperation within seven years;
- ***Product development programme*** (industrial biotechnology): the immediate objectives of the programme are to increase the sales of Estonian entrepreneurs, including export sales, as well as to foster the creation of new products and services with high added value. The focus is on applied research and product development by Estonian companies and research institutes;
- ***Technology investment support in industrial enterprises*** (advanced manufacturing technologies): the objective is to support international competitiveness of Estonian manufacturing companies and to support their re-orientation towards a knowledge-based economy, through technology investment support geared towards increases in productivity, export potential, product added value and the penetration of new markets. Main policy tools include support to sectoral innovation in manufacturing, support to technology transfer between firms, and support to organisational innovation including e-business and new forms of work organisation.

In general, RDI policy in Estonia is characterised by a combined approach to skills with a focus on tertiary and post-tertiary education, which includes activities that focus specifically on one KET, and which also includes activities that focus on KETs in general, and on skills in general. Policy initiatives are driven by the Ministry of Education and Research, the Ministry of Economic Affairs and Communications, and executed by organisations such as the Archimedes Foundation, and by Enterprise Estonia, which has a significant role in the implementation of RDI policies.

[39] Tallin University of Technology,2010, Policy Paper on Innovation: Estonia – report to the European Commission

[40] Eesti Arengufond, 2014, Estonia: Policy mix and implementation of the RIS3

[41] *Ibid*.

[42] https://webgate.ec.europa.eu/ketsobservatory/sites/default/files/policy/ESTONIA.pdf

Annex B: Good practices fostering mobility in KETs

Good practice examples presented in this Annex were nominated by the interviewed stakeholders. These examples cover different types of mobility in KETs.

Good practice example 1: VDW-Nachwuchsstiftung (Youth Education and Development Foundation), Germany

The current good practice example aims at fostering mobility between industry, vocational schools and universities within the machine tool sector.

VDW-Nachwuchsstiftung (German Machine Tool Builders' Association Youth Foundation) was founded by VDW in 2009. Located in Bielefeld, the Foundation's overall goal is the development and employment of youth in the machine tool sector. The Foundation specifically aims at transferring knowledge between industry, vocational schools and universities; quality improvement in vocational education; and increasing the number of apprentices and trainees in the machine tool sector.

The Foundation offers around 100 applied training courses (one course takes 3.5 days on average) with the help of machines and latest technologies for vocational school teachers and company training instructors. The courses are organised in partnership with Siemens and Heidenhain (companies) at their training centres due to access to the latest technology of control system available on the market. Additionally, the Foundation, in partnership with regional government, evaluates and certificates vocational schools in the area of computer aided manufacturing in terms of education quality. The Foundation also organises Skills Shows at machine tool exhibitions in Germany such as EMO Hannover, METAV Dusseldorf and AMB Stuttgart in order to improve the image of the machine tool sector and to attract more young people to the sector.[43]

Good practice example 2: AFM traineeship initiative, Spain

The current good practice example illustrates how a business association supports traineeship mobility in Advanced Manufacturing Technologies.

In 2015 AFM (Advanced Manufacturing Technologies - the Spanish Association of Manufacturers of Machine Tools, Accessories, Parts and Tools), launched an initiative stimulating traineeships abroad. Within this initiative, AFM will supervise 54 recently graduated Spanish young people who will spend 6 months working abroad. AFM prepares the selected trainees to the realities of working abroad before they are welcomed in host companies.

The programme does not create any financial burden for the host companies. The host organisation is responsible for planning the activities of trainees; assigning a tutor to supervise the work; and giving feedback about trainees' performance. Trainees are 30 years old or less, and they have a university or vocational training degree (mainly engineering, business studies and machining-mechatronic-assembly related vocational training degrees). Trainees receive a grant, managed by AFM, to cover all travel costs related to the internship location, accommodation and subsistence, and they are covered by a liability and travel insurance.[44]

Good practice example 3: IMH (the Machine Tool Institute), Spain

The current good practice example illustrates how companies and education providers cooperate at regional/national level through a business association by stimulating mobility between industry and academia.

The Machine Tool Institute (IMH) is a Technological Innovation Centre serving the industry and the community, through technical training and technological diffusion. The IMH, as an integral part of the AFM Group, is responsible for training the machine tool sector.

Specifically, the Dual Engineering University School of IMH offers an engineering university course combining academic training and gaining work experience in a company. This is an innovative

[43] More information can be found at: http://vdw-nachwuchsstiftung.de/index.php/home.html (VDW YF) or http://www.cecimo.eu/site/publications/magazine/skills/

[44] More information on AFM can be found at: http://www.afm.es/

study option which is directly related to the fact that companies require a workforce that is tailor-made to meet their needs. The project aims to improve engineers' training by integrating them in actual companies, and the institute reports that a high percentage of the students involved finds a job at the end of the training period.

Since it is carried out in both the company and training centre, the IMH Dual Engineering course enables students to gain first-hand experience of the day-to-day working of a company, and to channel their studies to meet their company's specific needs.

The result of this methodology is professionals who are well trained and capable of taking responsibility in different technical and management areas, and who furthermore have a thorough knowledge of the working of the company.[45]

Good practice example 4: Marie Curie Actions Initial Training Networks (ITN), European Union

The current good practice example represents a pan-European programme fostering mobility of researchers.

ITN offer early-stage researchers the opportunity to improve their research skills, join established research teams and enhance their career prospects. The participants can be universities, research centres or companies (large or small).

As of 2012, the Marie Curie Actions also offer the possibility to companies and institutions to propose two new formats of PhD training "the European Industrial Doctorates"(EID) and the "Innovative Doctoral Programme" (IDP). The objective is to strengthen the links between academia and industry, and to develop research careers combining scientific excellence with business innovation.

In the case of EID, only two participants are needed: one academic participant and one participant from the private sector. However, one of the conditions is that the researcher will have to be enrolled in a doctoral programme of the academic participant. The researcher will also spend at least 50 % of his/her time within the private sector.

Within IDP, single research organisations may sometimes get ITN support. One participant (university or research institution) offers an "innovative" doctoral training, i.e. with an international, public-private sector and interdisciplinary dimension. The training can then be completed with the participation of associated partners (other universities, research centres, private sectors, etc.).

Stakeholders also expressed their strong support for a similar programme for industry-industry exchange.[46]

Good practice example 5: Research and Innovation Staff Exchange (RISE), European Union

The current good practice example represents a pan-European programme fostering mobility of RDI staff between academia and non-academic organisations.

RISE funds short-term exchanges for staff to develop careers combining scientific excellence with exposure to other countries and sectors. RISE enables more interaction between academia and non-academic organisations within Europe and worldwide.

This action is meant for organisations such as universities, research centres or companies – that propose a short term exchange to their staff. Proposals should include at least three partners, which can be universities, research institutions, or non-academic organisations. Small and medium-sized enterprises (SMEs) are encouraged to participate.

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[45] More information on IMH can be found at: http://www.imh.eus/

[46] More information on ITN can be found at: http://ec.europa.eu/research/mariecurieactions/about-mca/actions/itn/index_en.htm

Partner organisations should be from three different countries. At least two of these should be from the EU or associated countries. Partners from elsewhere in the world can also join. If the exchange happens between the EU and associated countries, it must be inter-sectoral. In worldwide partnerships, exchanges within the same sector are possible.

Partners get together and propose a joint project. Proposals should highlight networking opportunities, sharing of knowledge and the skills development of staff members. Research staff of any nationality and any career level (postgraduates to experienced researchers) can undertake a secondment. Staff members working in managerial, technical or administrative roles can also be seconded.[47]

[47] More information on RISE can be found at: http://ec.europa.eu/research/mariecurieactions/about-msca/actions/rise/index_en.htm

ANNEX C: CASE STUDIES ON APPROACHES ALLOWING TO OPTIMISE SKILLS PORTFOLIO IN KETS

We developed 5 empirical case studies on HR management practices based on the interview data from a selection of KETs stakeholders. We developed concise descriptions covering the main details of the approach, including the essence of the approach, and its implications for the skills portfolio, as well as associated challenges and constraints.

Specific names of organisations are not being disclosed in the analysis due to anonymity guarantee of the results. Instead, we indicate the type of organisation, its size and the relevant KET(s) it works in, in order to specify the relevant context.

TABLE C-1: Case study descriptions on approaches allowing to optimise skills portfolio in KETs

Subject	Description
Case study Nr	Case study 1: ORGANISATION A
Organisation type	Research institute
Size	Large
Associated KET(s)	NT
Approach	Approach towards attracting new people • In order to attract new people, Organisation A heavily relies on the networks of their researchers and contacts from partner companies (these two sources bring them about 40-50% of all new people). This search is accompanied by vacancy announcements on their website and by mobilising LinkedIn resources. • Advertisement campaigns are of less relevance to them since they often hire people from abroad and these people are scattered across the globe, so it is difficult to target their audience. Furthermore, Organisation A is well known in their field, and people often find them themselves. • For less specialised roles (e.g. cleanroom operators), they work with recruitment agencies and they place advertisements in local newspapers. • Organisation A uses different approaches for hiring researchers and for positions that require a more standardised skill-set (e.g. cleanroom operators). The selection of the latter is coordinated by their HR people. There they can formulate in non-technical terms what kind of skills are needed for the job. For researchers, in turn, often a highly specific profile is required. The selection is then done by a line manager of a specific team that has this open position, in cooperation with HR when it comes to the assessment of 'soft'/non-technical skills. The final decision is then taken jointly, with the opinion of line managers having a higher weight in the final decision.
Implications for the skills portfolio	Organisation A receives a lot of applications for their open positions (on average 30-40 applications per position), so they can choose the best ones. There are only two fields for which they never can fill their open positions to a sufficient extent. Those include RFIC designers and System architects. Organisation A hires them whenever they find them. For the rest, such as operators or technicians, they always have enough applications to make a good selection.
Challenges and constraints	Organisation A does not want their people to stay too long. Local people typically stay longer than needed (they view it as a lifetime job). Foreign people typically leave earlier than needed (before they even get a promotion to the next career level). Organisation A has a relatively low employee turnover which on the one hand ensures stability of their skills portfolio, but on the other hand, jeopardises its continuous renewal.
Case study Nr	Case study 2: ORGANISATION B
Organisation type	Company

Size	Large
Associated KET(s)	IB
Approach	Approach towards attracting new people One of the key sources of new employees for Organisation B refers to job fairs held at schools/universities. Organisation B promotes itself on such fairs and tries to spot talented individuals. In addition, Organisation B has an internet tool that provides an overview of external vacancies. As a professional or student, one can sign in and receive the relevant job information. Organisation B always aims for internal and external applicants for each position, to make a comparison between outside offering and inside. The R&D department initiates the recruitment process and makes the job descriptions. The latter are then provided to HR managers, who subsequently drive the recruitment process. With the final 4 to 5 candidates of the selection process, the R&D personnel gets involved to make the final selection.
Implications for the skills portfolio	Organisation B is an HR-intensive company. Their HR department deploys all state-of-the-art processes to attract new employees. Organisation B hires people that are technically focused. Most of their people are innovative and highly educated in technical skills.
Challenges and constraints	No specific challenges or constraints were identified.
Case study Nr	Case study 3: ORGANISATION C
Organisation type	Research institute
Size	Small
Associated KET(s)	NT, AM, AMT
Approach	Approach towards attracting new people Organisation C is well known in its field of work. Attracting new people mostly takes place through personal contacts/networks of researchers or faculty staff. On average, Organisation C receives 5 to 10 requests per day. Organisation C is in its essence a department of a larger organisation (university), with the latter combining research, education and administration. Organisation C focuses on research, while HR department is located at the faculty. This is where so called 'soft skills' are present. Approach towards organising HR functions The faculty's HR department is traditionally shaped, with general functions and people often lacking technical insight into the area they are servicing. This could be improved by keeping the links between the researchers/research department and the HR department that should serve them, very close. In addition, HR personnel needs to have some experience/affinity with research. This would also enable a better level of commitment. Ideally, every appointment would be a one-of-a-kind project, specifically assessed on the job requirements and qualities of the individual aiming to fulfil the job.
Implications for the skills portfolio	While Organisation C does not have many issues with attracting new people, the selection process is complicated by poor connection between researchers and HR personnel.
Challenges and constraints	The educational level and level of commitment of HR managers needs to improve. Every technical focus area should be covered by a dedicated HR manager, who is informed on education, valorisation and research within that specific technical area of expertise. This way, students/researchers from outside the country will also require better guidance.
Case study Nr	Case study 4: ORGANISATION D
Organisation type	Company
Size	Small
Associated KET(s)	NT
Approach	Approach towards organising HR functions Organisation D does not have dedicated HR managers. Recruitment is

	the responsibility of the directors within each business unit. To ensure a fair standard across the business, working conditions are determined at the group level, but business units are responsible for recruitment. Approach towards attracting new people Organisation D has a good reputation in the region, and as a result, potential candidates typically come to Organisation D themselves. For instance, Organisation D does not tie in employees with a non-compete clause, but stimulates employees to stay at the company by providing them the opportunities they seek. Moreover, employees at Organisation D have a technical background and their own network in this industry, which has proven to be effective for promoting the company. Organisation D also makes use of social media, LinkedIn, and their own website to promote the company. Finally, they sponsor student associations in the relevant fields and have supported events such as seminars, including a seminar at which Stephen Hawking was a speaker. This increases visibility of the company among students.
Implications for the skills portfolio	Organisation D has a good visibility in the region, especially among students, and is considered an attractive place to work in. As a result, Organisation D does not have specific issues regarding attracting new people.
Challenges and constraints	No specific challenges or constraints were identified.
Case study Nr	Case study 5: ORGANISATION E
Organisation type	Research institute
Size	Large
Associated KET(s)	NT, AMT, AM
Approach	Approach towards attracting new people The approach depends on the goal. For each position at Organisation E, the technical aspects and technical skills are highly important in order to work in a lab. However, they also have business development people, and their skills are quite different. Nevertheless, they always require some technical background. People also need to be open-minded. Whenever new people are required, there is a large pool to choose from in the region. The region educates a large number of graduates, and Organisation E is one of the biggest employers in this field in the region, with a strong reputation. For some specific positions, e.g. management positions at the European office or scientific divisions, it is often necessary to look for someone outside the country. For other positions, however, many people just apply for the position on the website and as a result, Organisation E receives a lot of applications. HR tends to be more active in the recruitment of (higher) management positions. Approach towards organising HR functions Organisation E has a special division that determines the HR strategy of all R&D and technical divisions. Those people are not at all scientific, but very well know the profile of the people working there. They are competent in choosing the right person. These people are not 'classical' HR people. They are trained to help R&D and technical divisions on a particular subject and they work a lot on the KETs skills / KETs profiles.
Implications for the skills portfolio	Organisation E has a good visibility in the region, including students, and is considered an attractive place to work in. As a result, Organisation E does not have specific issues regarding attracting new people.
Challenges and constraints	One of the key challenges is that HR managers need to understand what they need to look for in candidates and to be able to assess this during the application process.

ANNEX D: REFERENCE LIST

Relevant reports and other publications:

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3. CECIMO (2013) "The European machine tool industry's Manifesto on skills", September 2013

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7. NanoEIS (2013) "Report on European industry needs", deliverable nr. D2.1, June 2013, led by PRODINTEC

8. Nikulainen, T., and Palmberg, C. (2010) "Transferring science-based technologies to industry — Does nanotechnology make a difference?", Technovation, 30(1), 3-11

9. Palmberg, C. (2008) "The transfer and commercialisation of nanotechnology: a comparative analysis of university and company researchers", The Journal of Technology Transfer, 33(6), 631-652

10. Proceedings of the workshop on KETs Skills organised by KETs HLG Sherpa Group of 10 June 2014

11. Proceedings of the workshop on Education, Training and Skills for electronic/photonic components and smart/embedded systems[48] organised by DG CONNECT of 5 May 2014

12. PwC (2014) "Vision and Sectoral Pilot on Skills for Key Enabling Technologies", Interim Report, prepared for DG GROW of the European Commission, Service contract nr. SI2.ACPROCE060233200

13. Singh K.A. (2007) "Nanotechnology skills and training survey", Institute of Nanotechnology

14. SEMTA (2009) "Skills and the future of Advanced Manufacturing: A Summary Skills Assessment for the SSC Advanced Manufacturing Cluster", December 2009

Relevant web links:

1. "Collective competence: More than a collection of competent individuals", Royal College, The ICRE Blog, published on 3 June 2014:

   http://icreblog.royalcollege.ca/2014/06/03/collective-competence-more-than-a-collection-of-competent-individuals/

2. First Sustainable Nanotechnology School project website:

[48] Although electronic/photonic components and smart/embedded systems do not belong to the NMBP area, they are part of KETs and many of the conclusions of this workshop are of high relevance to NMBP.

http://www.unive.it/nqcontent.cfm?a_id=66712

3. Homepage of Key Enabling Technologies of DG GROW of the European Commission:

   http://ec.europa.eu/enterprise/sectors/ict/key_technologies/

4. Homepage of Key Enabling Technologies of DG RTD of the European Commission:

   http://ec.europa.eu/research/industrial_technologies/index_en.cfm

5. Innovation union scoreboard website:

   http://ec.europa.eu/enterprise/policies/innovation/policy/innovation-scoreboard/index_en.htm

6. KETs Observatory country policy profiles:

   https://webgate.ec.europa.eu/ketsobservatory/sites/default/files/policy/ESTONIA.pdf

7. Luxembourg Portal for Innovation and Research, Researcher Mobility:

   http://www.innovation.public.lu/en/recherche-publique/mobilite-chercheurs/index.html

8. NanoEIS project website:

   http://www.nanoeis.eu/

9. NanOpinion project website:

   http://www.nanopinion.eu/en/education

10. QualityNano project website (the European Union-funded infrastructure for Quality in nanomaterials safety testing):

    http://www.qualitynano.eu/

ANNEX E: LIST OF INTERVIEWEES

TABLE E-1: List of interviewed stakeholders

Nr	Name	Position	Organisation, country	Type	KET
1.	Dr. Francine Papillon	Coordinator	CEA, GIANT/MINATEC, France	Research institute, cluster organisation	NT
2.	Prof. Rudy Lauwereins	Vice President IMEC Academy	IMEC, Belgium	Research institute	NT
3.	Prof. Dave H.A. Blank	Scientific Director	MESA+, Netherlands	Research institute/university	NT
4.	Robert van Tankeren	Director	TMC Physics, Netherlands	SME	NT
5.	Emir Demircan	Project coordinator	European Association of the Machine Tool Industries, Belgium	Industry association	AMT
6.	Mr. Chris Decubber	Research Programme Manager	EFFRA, European Factories of the Future Research Association	Research association	AMT
7.	Prof. Dr. Albert Duschl	Project Coordinator	Nanotechnology Education for Industry and Society, University of Salzburg, Austria	University	NT
8.	Stefano Perini	Coordinator Manuskills project	Politecnico di Milano, Italy	University	AM
9.	Dr. Jacqueline Lecourtier	NATF Fellow	National Academy of Technologies of France, France	Academia	Multi-KETs
10.	Prof. Roger De Keersmaecker	Co-chair of Working Group on KETs skills and education	IMEC, Belgium	Large company, Advisor to policy makers	Multi-KETs
11.	Prof. Carlos Freixas	Director of Marketing,	Roche Diagnostics, Spain	Large company	IB
12.	Dr. Danail Hristozov	Senior research scientist	Università Ca' Foscari Venezia, Italy	Academia	NT
13.	Arnaud Tandonnet	Apparel global sustainability director	INVISTA, Switzerland	Large company	AMT, IB
14.	Bruno Lepitre	President	Sustineo 2D, France	SME	AMT, IB
15.	Prof. Dr. Ing. Christian Bonten	Director	Institut für Kunststofftechnik (IKT) – Universität Stuttgart, Germany	Academia	AMT, IB
16.	Dietrich Wittmeyer	General Secretary	ERRMA, EU	Industry association	AMT, IB
17.	Melanie Williams	Owner, founder, Horizon reviewer	MelanieWilliams Consulting, United Kingdom	SME	AMT, IB
18.	Barbara Gall	Manager Strategic Marketing and Business Development	UPM GmbH – the Biofore company, Finland	Large company	AMT, IB

19.	Heleen de Wever	Project manager biotechnology	VITO, Belgium	Academia	AMT, IB
20.	Stefan Rutyers	Bioinnovation agent	Ghent Bio-economy Valley, Belgium	Cluster organisation	AMT, IB
21.	Anymous	Chief Commercial Officer	Anonymous SME	SME	AMT, IB

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KI-04-15-765-EN-N

This report represents the final report for the "Study on skills related to KETs". The general objective of the study is to provide the Commission with the analysis and recommendations on skills in the NMBP areas, aiming to tackle the growing skills imbalances, both from the Horizon 2020 and from policy perspectives. Specifically, the study aimed to develop recommendations on how Horizon 2020 can help tackle the issue of skills imbalances in the NMBP areas. Also, the study includes recommendations for other relevant Research & Innovation policy measures to tackle the skills imbalances in KETs. The recommendations are structured along the four thematic areas of technical skills, mobility, entrepreneurial skills, and HR management skills. The results of the study are primarily to be used for fostering skill-related activities in research-based projects, while also considering an opportunity to embed the skills aspects into the monitoring activities of such projects.

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ISBN 978-92-79-52300-7