mKETs-PL working document

Country report Ireland

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Content

1. Policy perspective

Irish research & innovation policy has strongly oriented towards Key Enabling Technologies for many years. The 1999 Technology Foresight Exercise paid significant attention to 'key enabling technologies' [ICSTI, 1999]. The Foresight report recommend focusing of Ireland's research and innovation efforts on increasing in national capability in niche areas of information & communication technologies (including underpinning enabling 'hardware' technologies such as photonics, nanotechnology, advanced materials, and micro-/nanoelectronics) and biotechnology. More recent analyses, including the 2012 Research Prioritisation Exercise reinforced this alignment with KETs, highlighting a number of critical 'science and technology platforms' expected to underpin the identified research priority areas, including: Nanotechnology; advanced materials; microelectronics; photonics; and biomedical science [underpinning novel biotechnologies].

In Section 1.1, we discuss the Irish innovation system in the context of KET. In particular, we briefly review recent Irish government policy documents relevant to pilot lines and KETs (e.g. a report of the Research Prioritisation Steering Group and the report on the future of manufacturing in Ireland). We also give an overview of the key stakeholders in the Irish innovation system, including key government departments and advisory bodies; research & innovation funding agencies; intermediate R&D organisations; research & technology centres (funded by government innovation agencies); as well as examples of key industrial research, development & manufacturing operations.

In Section 1.2, we briefly discuss the limited Irish policy discourse related to multi-KETs, in the context of Ireland's declared research priorities.

In Section 1.3, we give a brief overview of policies and governmental programmes that could be used to address manufacturing-related innovation challenges associated with KETs.

1.1. Irish innovation system with emphasis on KET

Policy makers interviewed in course of this study strongly supported the Horizon2020 focus on KETs and the importance of R&D facilities to address the 'manufacturability challenges' of KETs. The Irish Government's response to the EC Green Paper [Forfás, 2011] emphasized ongoing support for enabling technologies such as ICT, biotechnology and nanoscience and for underpinning policy research. The response points to the importance of achieving a suitable balance between research and pilot demonstration activities.

In the context of any future KET 'pilot line' programme, policy makers highlighted the importance of understanding of who would capture the value from any 'pilot line' facilities; whether there would be any training or other social returns; and whether there would be opportunities for other members of the relevant industrial cluster or supply chain to benefit.

There was no clear consensus among policy makers about the definition of 'pilot line' but, in the context of a publically funded programme, it was generally assumed to mean a facility which would enable multi-party access to equipment, tools and infrastructure to work out range of 'manufacturability challenges' associated with platform KETs. Existing (publically funded) KET-related production technology demonstration facilities in Ireland are limited to activities of some technology R&D centres that address 'modularised' bits of pre-pilot-line demonstration, test and validation. There was significant interest in the potential of an EU 'pilot line' programme that also allowed for testing of these technologies in a 'pilot process line'.

An important contextual factor in Irish policy making towards KETs is the dominant role played by foreign multi-national firms within the Irish economy. Foreign MNCs make up 30% of Gross Value Added in the Irish

economy (much of this high-end manufacturing); accounting for more than two-thirds of all exports. Dominant sectors within which these MNCs firms operate include strongly KET-based activities such as industrial biotechnology (e.g. Pfizer biopharma) and micro-/-nanoelectronics (e.g. Intel). Furthermore, these foreign MNCs carry out nearly three-quarters of all private sector research, development and innovation in Ireland. Inevitably, much publically-funded industry-relevant research activities in Ireland are aligned with these KET domains and the research interests of the R&D-intensive manufacturing firms operating in Ireland.

A summary of KET 'performance profiles' for Ireland (i.e. patent activity, important innovation system actors and trade activities) can be found in the EU Commission Report '*Exchange of good policy practices promoting the industrial uptake and deployment of Key Enabling Technologies*' [IDEA Consult, 2012]. Ireland has significant patenting activity across most KET domains, as well as high levels of international trade in some KET-based products, notably industrial biotechnology and micro-/nano-electronics.

The two most recent Irish government policy documents relevant to pilot lines and KETs are:

- **The Report of the Research Prioritisation Steering Group** [Forfás, 2012]
- **Making it in Ireland: Manufacturing 2020** [Forfás, 2013]

The Irish Government's Research Prioritisation Exercise:
In 2010, the Irish Minister for Enterprise, Trade and Innovation convened a high-level expert group to work on a five year prioritisation plan for Government investment in research and 'smart' jobs. The research prioritization process included a major stakeholder engagement exercise focusing on identifying where Ireland should best focus research efforts and tailor government R&D investments. The process also engaged national and international experts from the private and public sector, as well as senior Government officials and draw on international experts who have completed similar exercises within other national innovation systems.

The results of this exercise were published in a report published in 2012 [Forfás, 2012]. This report, which was adopted by Irish Government, identifies 14 priority areas that will become the focus of future State investment in research and innovation. These priority domains build on existing Irish research strengths and investments, and target future government investments towards research efforts which will further develop the Irish innovation system as a location for knowledge and innovation intensive enterprises and jobs for the future. The high level criteria for assessment of research priority areas are listed below (Table 1).

1	The priority area is associated with a large global market or markets in which Irishbased enterprises already compete or can realistically compete
2	Publicly performed R&D in Ireland is required to exploit the priority area and will complement private sector research and innovation in Ireland
3	Ireland has built or is building (objectively measured) strengths in research disciplines relevant to the priority area
4	The priority area represents an appropriate approach to a recognised national challenge and/or a global challenge to which Ireland should respond

Table 1: The Four High Level Criteria for Assessment of Research Priority Areas

The research prioritsation exercise highlighted a number of areas directly relevant to pilot lines and KETs. In particular, the report identified 'manufacturing competitiveness' and 'processing technologies & novel materials' as priority research domains to enable the Irish manufacturing base to transition into one with enhanced capabilities in processing technologies and materials science and engineering.

A	Future Networks & Communications
B	Data Analytics Management, Security & Privacy
C	Digital Platforms, Content & Applications
D	Connected Health & Independent Living
E	Medical Devices

F	Diagnostics
G	Therapeutics - synthesis formulation, processing and drug delivery
H	Food for Health
I	Sustainable Food Production and Processing
J	Marine Renewable Energy
K	Smart Grids & Smart Cities
L	Manufacturing Competitiveness
M	Processing Technologies and Novel Materials
N	Innovation in Services and Business Processes

Table 2: Recommended Priority Areas of Focus

The research prioritisation exercise also highlighted a number of important 'science and technology platforms' expected to underpin the identified research priority areas. Several of these underpinning research domains have a strong correspondence and/or underpinning relationship with the Horizon2020 KETs.

1	Nanotechnology
2	Advance Materials
3	Microelectronics
4	Photonics
5	Basic Biomedical Science
6	Software Engineering

Table 3: Identified 'platform science & technology areas'

The positioning of the 14 priority focus areas and the platform science and technology areas in a wider context of the Irish science, engineering and technology R&D portfolio is illustrated in Figure 2 below.

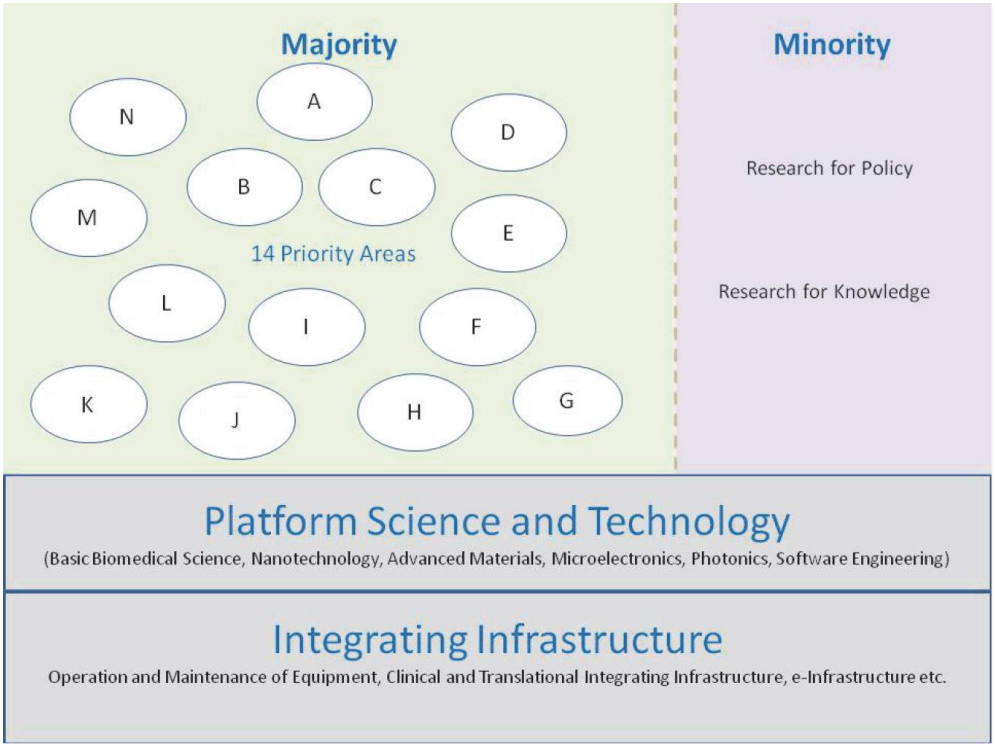

Figure 2: Priority Areas and the Wider STI System [SOURCE: Forfás, 2012].

The Irish Government's Manufacturing 2020 strategy

The Irish government's recent manufacturing strategy [Forfás, 2013] highlights the critical need for Ireland to '*remain abreast of, and aligned with, the RD&I focus within the EU. Of particular interest from a manufacturing perspective is the focus on what the EU calls Key Enabling Technologies (KETs)…*' The report goes on to identify perceived areas of opportunity for manufacturing activities in Ireland that are relevant to the mKET pilot line agenda:

- **Contract manufacturing:** The Manufacturing2020 strategy highlights the role of contract manufacturing organisations in: alleviating start-ups' need for capital investment; offering an attractive value proposition for overseas entrepreneurs; and bringing together development, design and engineering capabilities for new product introduction and process development
- **New Product Introduction/Pilot Manufacturing:** The Forfas Manufacturing Strategy highlights the potential for Ireland to position itself as a location for piloting/testing new products and developing efficient and sustainable production systems. The strategy emphasises the potential for actions which could support the development of appropriate test/trial and scale-up facilities which also leverage the existing R&D expertise
- **Advanced materials:** The Manufacturing 2020 strategy also points to opportunities related to advanced materials, in particular the importance of developing next generation analytics for characterisation and next generation processes for manufacture. The strategy acknowledges the manufacturability challenges of advanced materials pointing to the importance of developing novel processing or forming, as well as coating and surface engineering capabilities and competencies
- **Importance of Engineering and Applied R&D capabilities:** The lack of facilities that firms can avail of to trial and test new products and manufacturing processes has also been highlighted as a specific issue, particularly in the context of the capital intensity of the sector.

Main stakeholders in Ireland

Stakeholders in the Irish innovation system with activities and interests relevant to KET-related pilot lines include: Government departments and advisory bodies; governmental innovation and economic development agencies; intermediate R&D organisations; national research & technology centres (funded by innovation agencies); and R&D-intensive firms in sectors such as industrial biotechnology (biopharma) and micro-/nano-electronics. An overview of Irish research and innovation system is summarized in Figure 1. More details about key stakeholders relevant to KETs and pilot lines are discussed below.

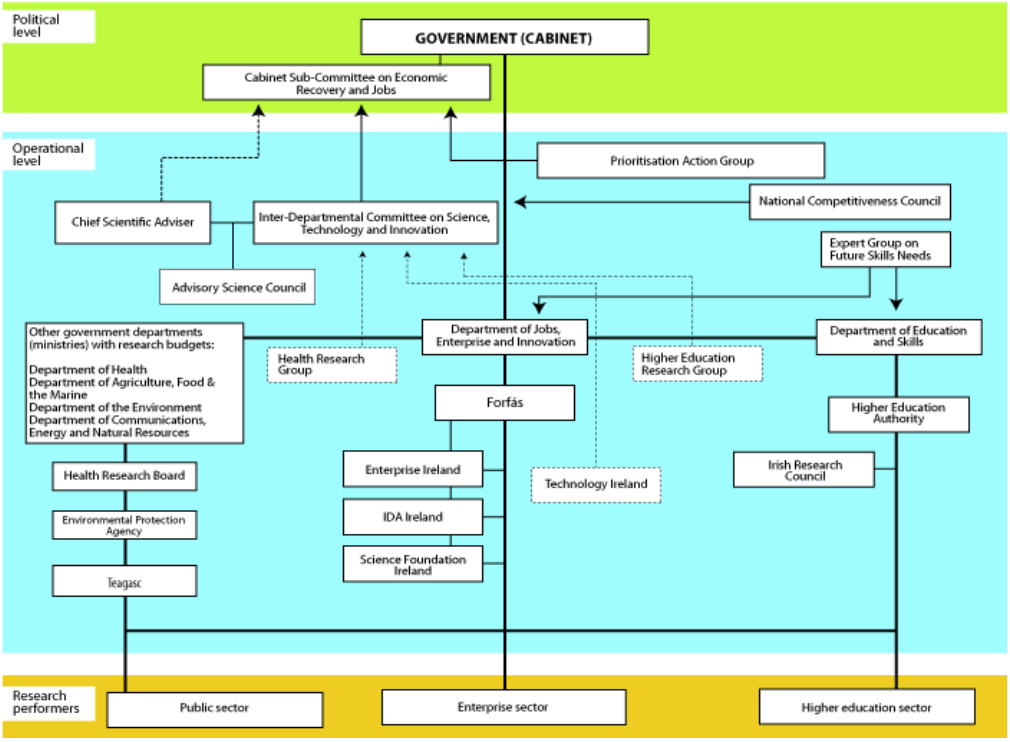

Figure 1: The structure of the research and innovation system in Ireland (SOURCE: ERAWATCH)

Government departments and advisory bodies:

- **The Department of Jobs, Innovation & Enterprise** (DJEI) is the Irish Government department responsible for the implementation of policy areas related to: enterprise, innovation, growth; quality work and learning; making markets and regulation work better; quality, value and continuous improvement; the european union.
- **Forfás** is Ireland's policy advisory board for enterprise, trade, science, technology and innovation. They provide independent and rigorous research, advice and support in the areas of enterprise and science policy. This agency also publishes periodically valuable information on national investments in research. It should be noted that in addition all of the research funding agencies are involved in policy development but mainly on their area of focus.

Governmental Research & Innovation Funding Agencies:

- **Science Foundation Ireland** (SFI) is the state agency responsible for distributing the largest amount of project-based research funding to the higher education sector. In 2008, SFI distributed €103 million on a competitive funding basis for research in the fields of biotechnology, ICT, sustainable energy and energy-efficient technologies.
- **Enterprise Ireland** (EI) is the government organisation responsible for the development and growth of Irish enterprises in world markets, working in partnership with Irish firms to help them start, grow, innovate and export to global markets. Enterprise Ireland also aims to facilitate collaborative links between Irish firms and the Irish research community focused on the practical application of research in business. EI offers a variety of support activities and funding programmes to companies that wish to engage in R&D.

- **IDA Ireland** – Ireland's inward investment promotion agency – is responsible for the attraction and development of foreign investment in Ireland. IDA Ireland support R&D by providing funding support for suitable projects and by helping client firms identify other programmes available from partner organisations such as Enterprise Ireland or Science Foundation Ireland.

Intermediate R&D Organisations:

- **Tyndall National Institute**
  The Tyndall National Institute is a research centre specialising in ICT hardware research, with over 400 staff, students and academic and industrial visiting researchers. Tyndall undertakes research into information and communications technology, with research centres addressing challenges related to: photonics, micro/nanoelectronics, microsystems, theory modelling and design, and wafer fabrication. Tyndall uses its facilities and expertise to support industry and academia nationally and provides large numbers of highly qualified graduate students

  Tyndall provides a wide range of services to industry and academia helping. The services available include wafer fabrication, test and measurement, intellectual property investigation, microscopy analysis, temperature and environmental characterisation, integration and packaging and many more. These professional services are provided on a commercial contract basis and are delivered by Tyndall staff. Access to equipment is also available for qualified industry personnel who wish to conduct the work themselves in a Tyndall laboratory.

- **National Institute for Bioprocessing Research and Training (NIBRT)**
  NIBRT is a training and research centre for bioprocessing. NIBRT's facilities is purpose built to closely replicate a modern bioprocessing plant with state-of-the-art equipment. NIBRT is based on an innovative collaboration between University College Dublin, Trinity College Dublin, Dublin City University and the Institute of Technology, Sligo. NIBRT was primarily funded by the Government of Ireland through Ireland's inward investment promotion agency, IDA Ireland (Industrial Development Agency), which is responsible for the attraction and development of foreign investment in Ireland.

  NIBRT is a purpose-built, multi-functional building which replicates the most modern industrial bioprocessing facility environments. The total building area is approximately 6,500 m² over two floors. At the heart of the NIBRT building is the bioprocessing pilot plant, consisting of extensive upstream, downstream, fill-finish and the associated analytical facilities. These facilities are all operated in a realistic GMP simulated, operational manufacturing environment. The facility also provides extensive research laboratory areas with ample capacity for our research teams and for our client companies.

- **Moorepark Technology Limited** (MTL) is a joint venture company established by Teagasc, the Irish Agriculture & Food Development Authority in cooperation with stakeholders from the Irish food industry. MTL provides pilot plant & research services for food industry firms. MTL operates a 'pilot plant facility' with versatile pilot-scale processing equipment and provides a range of services, including: Pilot plant rental; contract research & development; pre-commercial manufacture; technical assistance/advice/support.

- **GeorgiaTech Ireland (GTI):** GTI is an international office of the Georgia Tech Research Institute - a nonprofit applied-R&D organisation owned by the Georgia Institute of Technology. GTI provides support to Irish (and EU) industry by providing applied R&D and advanced engineering support services. The building of test beds to support R&D is an important element of GTI's activities, providing conditions that allow industry partners to rigorously test new technologies, tools and theories before they are implemented on a broad scale. GTI is developing test beds in a number of strategic technology R&D areas including health care technologies and sustainable energy.

- **Materials and Surface Science Institute (MSSI):** MSSI, based at the University of Limerick, carries out industrially-relevant research in areas of surface science and materials for applications in: Health, transport, energy and clean technology. MSSI's characterisation and sample preparation facilities are available for use by other institutions and industry.

Research and Technology Centres (funded by government innovation agencies):

The State's investments have served to provide an R&D infrastructure that is supportive of the needs of enterprise, thereby enhancing Ireland's attractiveness for investment in knowledge intensive activities by both foreign and Irish owned firms. The State has invested in establishing R&D centres including:

- **SFI Research Centres Programme**: Science Foundation Ireland runs a Research Centres Programme (formerly the Centres for Science, Engineering & Technology programme) designed to link scientists and engineers across academia and industry to address crucial research questions, foster the development of new and existing Irish-based technology companies, attract industry that could make an important contribution to Ireland and its economy. Centres must address one or more of the research priority areas identified in the Research Prioritisation report [Forfás, 2012]. Centres typically have strong engagement with the activities of major R&D-intensive firms based in Ireland and – because these activities are primarily manufacturing operations – manufacturing-related R&D challenges can be an important part of the research agenda. Science Foundation Ireland investment portfolio has a strong overlap with the identified Horizon2020 key enabling technologies, notably ICT hardware-related domains (such as advanced materials, nanotechnology, nano/micro) and biotechnology.

- **Technology Centres:** Enterprise Ireland (the state agency responsible for the development and growth of indigenous Irish enterprises) and IDA Ireland (the national inward investment agency) run the Technology Centres programme as a joint initiative. The focus of the R&D undertaken by the Technology Centres has been set by industry, and a number of the Centres are involved in R&D that is of direct relevance to manufacturing activities and/or manufacturing related sectors. Currently funded Technology Centres address a number of domains that are closely aligned with the Horizon2020 key enabling technologies, including: industrial biotechnology (biorefining and bioenergy), applied nanotechnology, composite materials, microelectronics, and manufacturing research

Industrial Research, Development & Manufacturing Operations, for example: Pfizer (Ireland); Intel (Ireland):

- **Pfizer Grange Castle Biotechnology Campus:** Pfizer runs a €1.8 billion biotechnology facility on a 90-acre site in Grange Castle, South County Dublin. The Grange Castle site – part of the Pfizer Specialty Biotech manufacturing network – is one of the world's largest integrated biotechnology plants in the

world. As well as commercial operations manufacturing biologically active ingredients (e.g. for parenteral products and vaccines for preventing pneumococcal disease) and investigational medicinal products for use in clinical trials, the Grange Castle facility has significant development operations including: state-of-the-art pilot-plant, laboratories and equipment for the development of processes for production of many different types of biological drugs, including proteins and vaccines.

- **Intel Technology and Manufacturing Research in Ireland:** The Intel Technology and Manufacturing Research Team carries out activities in KET-related areas such as: semi-conductor manufacturing (such as advanced process control and energy efficiency) and nanotechnology (including research into nano-materials synthesis and integration, nano-photonics and silicon spintronics). Research in these domains takes place both on Intel's factory operations in Leixlip, County Kildare and collaborating public sector research organizations, including: The SFI-funded Centre for Research on Adaptive Nanostructures and Nanodevices (CRANN); the Tyndall National Institute; under the auspices of the EU's Framework Programme for Research and Technology Development (RTD). Intel Technology and Manufacturing Research Team (along with other industry stakeholders) played a significant role in establishing three Technology Centres (see above): The Energy Efficiency Competence Centre (which carries out research to support Irish manufacturing companies reduce their environmental impact of their energy use), the Irish Centre for Manufacturing Research; and the Competence Centre for Applied Nanotechnology (CCAN).

1.2. Organisation of mKETs policy in Ireland

In this section we briefly discuss the limited Irish policy discourse related to multi-KETs, in the context of Ireland's declared research priorities.

As discussed above, the Report of the Research Prioritisation Steering highlighted a number of important *'science and technology platforms'* expected to underpin the identified research priority areas. These underpinning research domains have a strong correspondence with the KETs (as well as reflecting areas of significant research investment by agencies such as Science Foundation Ireland):

- **Nanotechnology**
- **Advanced Materials**
- **Microelectronics**
- **Photonics**
- **Software Engineering**
- **Biomedical Science [*underpinning novel biotechnologies*]**

Furthermore, a number of the research priority areas have particular relevance to the debate regarding KET-based 'pilot lines' (and the scale-up challenges of KET and mKET-based technologies), for example**:**

- **Manufacturing Competitiveness:** This priority area is focused on the development and application of technology and knowledge management systems to reduce costs, eliminate waste, drive resource efficiency and improve product quality for increased competitiveness.
- **Processing Technologies & Novel Materials:** This priority area is focused on enabling the Irish manufacturing base to transition into one with enhanced capabilities in processing technologies and materials science and engineering.

In the context of the Irish research prioritization exercise, it is clear that many important technology-based product innovations may rely on multiple KETs. In particular, the cross-cutting and pervasive nature of the 'advanced materials' and 'advanced manufacturing' KETs, mean that they are (inevitably) involved in many other KET-development processes: For example, application domains where Ireland has significant strengths such as biomedical devices and diagnostics are fundamentally cross-cutting fields potentially involving many KETs, for example: photonics, micro-electronics, nanotechnology, novel materials, (industrial biotech-produced) bio- and bio-compatible materials, as well as the advanced manufacturing technologies necessary to manufacturing them.

Some policy makers interviewed in the context of this analysis, raised questions about whether the multi-KET nature of a final application domain was, *in itself*, a useful prioritization criterion for public research investment. In particular, it was highlighted that it would be important to distinguish between those mKET domains which have important science and engineering research challenges associated with integrating KET technologies (and/or the scaling-up of integrated KET technologies). The prioritization of any research investments in such areas would have to taken within the context of existing prioritization and investment criteria (see Tables 1 and 2 above).

Furthermore, the importance of convergent technologies and multidisciplinary research is well recognized within the Irish research and innovation system. The recent Manufacturing 2020 report by the Irish government highlights the potential importance of convergent technologies (and sectors). Furthermore, flagship research investments, such as the SFI research centres programme (discussed above) involve

significant investments in domains where multiple KETs may be involved, e.g. biomedical diagnostics, optoelectronics.

1.3. Main policies for Pilot lines in Ireland

In this section we give a brief overview of policies and governmental programmes relevant to pilot manufacturing. Particular attention is paid to the policy discourse and government programmes relevant the manufacturing-related innovation challenges associated with key enabling technologies.

As discussed above, the Irish Government's recent Manufacturing2020 strategy emphasizes the important role of 'new product introduction and pilot manufacturing'. The report points to Ireland's potential as a location for piloting/testing new products and developing efficient and sustainable production systems; and emphasizes the importance of appropriate test/trial and scale-up facilities which also leverage the existing R&D expertise. This same report also pointed to the importance of engineering and applied R&D capabilities; as well as facilities that firms can avail of to trial and test new products and manufacturing processes.

Based on interviews and desk research for this study, however, there does not appear to be significant 'pilot line'-specific policies or governmental programmes in Ireland. Although many horizontal innovation policy measures (e.g. innovation vouchers) could, in principle, be used to address manufacturing-related innovation challenges associated with KETs.

Nevertheless, some governmental programmes do make reference to potential complementary R&D facilities, e.g. test beds (e.g. Enterprise Ireland's *Technology Innovation Development Award* and SFI's *Research Infrastructure Programme*), for example:

- **Technology Innovation Development Award (TIDA):** The Technology Innovation Development Award programme supported by Science Foundation Ireland and Enterprise Ireland is designed to enable researchers to focus on the first steps of an applied research project that may have a commercial benefit if further developed. TIDA funding is intended to "allow researchers to demonstrate the viability and robustness of their ideas or products in the context of competing technologies and market potential".

  The scheme can be sued to support researcher to avail of ***open-access test bed facilities***. As part of the TIDA programme, applicants are encouraged to use open-access test bed facilities to demonstrate their technology. Science Foundation Ireland hosts a list of national testbed facilities on its website: http://www.sfi.ie/links-resources/testbed-facilities-within-ireland/

- **Science Foundation Ireland Research Infrastructure programme:** Science Foundation Ireland's Research Infrastructure programme is designed to "to support the research community in building and sustaining the required infrastructural capacity to accomplish high quality, high impact and innovative research in areas of science and engineering that demonstrably enhance and underpin enterprise competitiveness and societal development in Ireland in a timely manner."

  Although this programme is for higher education research institutes, there is an emphasis on collaborative efforts and on liaison with industry with the goal of strengthening and sustaining Ireland's research base. Within this call, 'infrastructure' can include ***'test bed' facilities***.

2. Business perspective

This section provides a summary of the opinions and perspectives that were discussed through our interviews with companies in the Ireland. As with companies interviewed in the UK these companies expressed the view that their issues transcended national boundaries, they did not particularly think of themselves in national terms. This is especially true for large multinationals with a base in Ireland as they are responding to the local context conditioned by what the larger company strategy indicates.

Again the terminology of 'pilot production' was confusing, as each sector and each individual had their own interpretation of what pilot meant in their context. This has made the interviews very difficult in this context as without agreement on the base terminology, combined with a lack of familiarity in many cases with the key enabling technologies as set out by the Commission, much of the start of these interviews involved understanding which terminology to use.

2.1. Implementation of multi-KETs pilot lines

Perspectives on the definition of KET pilot lines: A number of interviewees identified different components of a KET 'pilot line': (1) novel *'unit' production processes* and associated technologies; (2) some element of *'logistical flow through'*, and (3) test *and validation* capabilities.

Many interviewees drew a distinction between a *'unit operation pilot line'* (testing a novel production technology or process) and a *'pilot process line'* which tested flow through a sequence of unit operations. Typically most interviewees interpreted the unqualified term *'pilot line'* as meaning a process pilot line approaching full manufacturing plant-like conditions and 'through rates'. For these business stakeholders, therefore, the term 'pilot line' was synonymous with 'manufacturing readiness level' 7.

There seemed general consensus, however, that a useful mKET 'pilot line' programme should address both individual 'unit operation R&D' as well as 'process line' endeavours (as various manufacturing readiness challenges are gradually overcome): "*There is no point in funding MRL7 if there is no coherent support for MRL 4 to 6 R&D*".

It is worth noting that the term 'pilot line' seemed less familiar to biotech-related actors, who were more comfortable with the term 'pilot plant'. The implication seemed to be that some industrial biotechnology-related manufacturability challenges did not have as many unit production operations in sequence within the manufacturing process.

Importance of skills and mobility to KET pilot line implementation: A repeated theme that emerged from business interviewees was the importance of staff mobility in implementing effective production-related R&D. In particular, it was important to be able to move expertise readily between research organisations, manufacturing engineering units and pilot production-related facilities.

Pilot line stakeholder interactions: A number of interviewees suggested that pilot line facilities would increasingly need to 'open innovation' modes of R&D collaboration and engagement. In this context, several interviewees pointed to challenges in initiating interactions between researchers in universities and R&D institutes, industry.

The ways in which risk (and investment) associated with piloting new processes or production technology equipment seemed to be distributed differently between equipment supplier firms and major 'user industry' firms. Very often, however, significant risk was borne by suppliers 'contractor' firms, with the larger company contributing design specifications and functionality requirements. Implementing effective pilot lines – i.e.

which delivered novel manufacturing technologies into the market sooner – could potentially be facilitated by ensuring that neither user industry 'customers' nor production technology 'contractors' took the full risk.

Several interviewees highlighted that one consequence the importance of close engagement between technology research the manufacturing R&D and demonstration was that pilot production endeavours usually take place close to the corporate R&D base. This posed potential challenges for engaging non-EU multinationals engaging in pilot line R&D within Europe.

KET Pilot line implementation – variations: It is worth noting that there were significant differences in perspective – seemingly related to technological, application and market maturity - on what the key challenges to implementing KET pilot manufacturing are. For example, a representative of the industrial biotech sector highlighted to the increasing need for pilot plant facilities that were very *flexible*, with lots of different types of equipment and facilities that were multi-purpose, multi-product. Representatives of the microelectronics industry pointed to the advantages of having a relatively clear sense of the size, nature and needs of their established market. Representatives of sectors with complex production technology *systems* highlighted the challenges associated with collaboration and 'open innovation'.

2.2. Evaluation of KET polcies/KET innovation eco-System

Irish KET policies and the 'innovation ecosystem': Interviewees from the Irish private sector broadly welcomed the KET-related R&D priorities identified in the Irish government's recent Research Prioritisation Exercise and the research-related goals of the Manufacturing 2020 strategy. There was general agreement that these initiatives would lead to the enhancement of the Irish innovation ecosystem in the context of addressing the manufacturability challenges of KETs relevant to the Irish economy. Furthermore, both of these initiatives were considered well aligned with the goals of the proposed EU mKET pilot line programme. Irish firms were positive about Science Foundation Ireland's attention to the engagement between university researchers and industry (typically manufacturing-related operations of MNCs).

The KET innovation ecosystem – people & skills: An important 'innovation ecosystem'-related theme in most business interviews was the importance of being able to move people readily between research organisations, industry (manufacturing and R&D units) and 'pilot line'-related facilities. There seemed strong agreement that this was critical (researchers needed to be able to 'follow the technology') and that KET-related programmes which supported and facilitated this mobility would be of significant value.

A related 'KET innovation ecosystem' skills theme was highlighted by a number of business interviewees: A key output of 'pilot line'-like facilities is the people with skills to run next generation production facilities within firms. In this context, turnover of staff from any mKET-pilot line facilities should be encouraged. Currently, there are not enough engineers of this type being generated within the ecosystem.

It was also suggested that many current KET-related production demonstration and test facilities may not fulfil their potential to provide training on next generation production technologies and processes. There is a significant opportunity for any mKET pilot line facilities to provide such a role, as well as giving science and engineering graduates experience in advanced manufacturing, good manufacturing practice, and working in industry environment.

The KET innovation ecosystem – EU Programmes: For many companies, there was a sense that some tradition EU KET-related programmes did not appropriately prioritise investments addressing the manufacturability challenges of emerging system technologies which required complex technological integration. While there was no clear consensus on what the term 'multi-MET' might mean, there was significant support for a 'pilot line'-related programme that prioritized facilities to address the manufacturability of complex technologically integrated systems.

For companies in the micro-/nano-electronics domain, there was a strong sense that production technology demonstration facilities *of significant scale* were missing from the current eco-system of innovation support programmes. And that this put the EU at a potential competitive disadvantage in strategically important industrial domains (e.g. next generation microelectronics chip fabrication).

A common theme in many interviews was the difficulty for industry in navigating the complexity of EU funding programmes. In particular, it was highlighted that the nature of industrial R&D means it is essential to have appropriate timings and flexibility. Furthermore, joint research agreements need to be more 'organic and bilateral' rather than requiring full commitment to long-term projected goals (with associated inflexible progress and financial reporting).

KET Policies - Translation from discovery to manufacturability: Governmental / EU KET-related R&D programmes should be designed to ensure effective translation between the different technology- and manufacturing-readiness level activities. Care should be taken to not open up any 'gaps' between more 'discovery'-related research and 'manufacturability'-related R&D.

Some interviewees suggested that previous Framework programmes were weighted too heavily towards discovery with not enough attention to the scale-up R&D challenges of KETs.

KET Policies – open innovation: A number of interviewees suggested that some current KET-related demonstration facilities were not fully compatible with evolving models of 'open innovation' modes of R&D. And that the design of any future EU mKET Pilot Line programme should account for this. Some interviewees pointed to challenges in initiating interactions between researchers in universities and R&D institutes, industry, and organisations with 'pilot line'-related facilities.

Pilot lines informing future KET policies: A couple of interviewees made the point that pilot line facilities could themselves be a potentially useful source of ongoing evaluation information on the KET innovation system. They are well placed - through their interactions with industry and academia – to identify shortcomings in the innovation system (in terms of research, skills, infrastructure); to monitor the evolving priorities of emerging technology based industries; and to help shape the KET policies of the future.

3. Conclusions

3.1. Summary of policy perspective

Irish policy makers appear to be strongly supported the Horizon2020 focus on KETs and the importance of R&D facilities to address the 'manufacturability challenges' of KETs. There has been significant focus on KETs within Irish research and innovation policy since 1999 through a number of Foresight and Prioritisation exercises. Because of this there are both relatively clear policies towards KETs as well as a number of KET-related applied R&D and competence centres around the country which interact closely with the Irish manufacturing base. There is a clear statement of intent in the Irish Manufacturing Strategy to become a centre for pilot and scale production for new products

Policy makers highlighted the importance of understanding of who would capture the value from any 'pilot line' facilities; whether there would be any training or other social returns; and whether there would be opportunities for the rest of the relevant cluster or supply chain to benefit (beyond the participating firms?

There was no clear consensus among policy makers about the definition of 'pilot line', but in the context of a publically funded programme, it was generally assumed to mean a facility with significant 'spillover' benefits to the broader industrial innovation system – a facility that allowed for multi-party access to equipment, tools and infrastructure to work out range of 'manufacturability challenges' associated with platform KETs.

Existing (publically funded) KET-related production technology demonstration facilities in Ireland are limited to activities of some technology R&D centres that address 'modularised' bits of pre-pilot-line demonstration, test and validation. There was significant interest in the potential of an EU 'pilot line' programme that also allowed for testing of these technologies in a 'pilot process line'.

3.2. Summary of business perspective

Although there is no clear consensus among industry stakeholder on the semantics of the term 'pilot line', there seemed general consensus that any useful mKET 'pilot line' programme should allow for research that demonstrates the viability of individual novel production 'unit operations' as well as addressing the challenges of integrating sequences of unit operations together in 'pilot process lines'.

Several business interviewees highlighted that the importance of close engagement between technology research, manufacturing R&D and demonstration. They further commented that one consequence of this was that pilot production facilities usually take place close to the corporate R&D base. This posed potential challenges for the engagement of Ireland's non -EU multinationals manufacturing base engaging in pilot line R&D within Europe.

The potential role of 'pilot line'-related facilities to develop of skilled people is seen as critically important; and any programme should ensure that this element is prioritised. The mobility of research and engineering staff between firms, pilot line facilities and research organisations is also considered an important element in the effective implementation of pilot line facilities.

The business representatives interviewed in the course of this study were supportive of the Irish governments research prioritization and manufacturing strategies; which were generally believed to be well aligned and complementary with the goals of the proposed KET pilot line initiative.

3.3. Recommendations to support pilot lines

The following 'recommendations' are based on points where there seemed to be significant consensus among Irish policy and business representatives interviewed in the course of this study:

- mKET pilot line facilities could usefully address both individual 'unit operation R&D' as well as 'process line' endeavours
- The governance structure of any mKET pilot line initiatives should include representation of all stakeholders
- Industry engagement models for any mKET pilot line facilities should be compatible with evolving models of 'open innovation' modes of R&D
- There may be potential for mKET pilot line facilities to have an important training and capacity building function – in particular producing EU researchers and manufacturing engineers with experience at the cutting edge of latest KET production technologies
- Care should be taken to not open up any 'gaps' between more 'discovery'-related research programmes of Horizon2020 and 'manufacturability'-related R&D programmes (e.g. mKET pilot lines): "*The bridge across the valley of death shouldn't have any holes*".
- Any cost sharing requirements and industry partnership arrangements for mKET pilot lines should be designed so that user industry ('customer') partners and production technology ('contractors') supplier partners appropriately share development risks

4. References

4.1. Literature

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4.2. Interviews

Name	Organisation
John Boland	Director of the Centre for Research on Adaptive Nanostructures and Nanodevices (CRANN) Trinity College Dublin
Eamonn Cahill	Senior Policy Analyst, Forfas (Ireland's policy advisory board for enterprise, trade, science, technology and innovation) Ex-industry (Hitachi)
Leonard Hobbs	New Business Development, Intel Head of Intel Technology and Manufacturing Research Team in Ireland Leader of the European NanoTechnology Research Program at Intel
Declan Hughes	Manager, Enterprise and Trade Division, Forfas (Ireland's policy advisory board for enterprise, trade, science, technology and innovation)
Anonymous	Industry (micro-/nanoelectronics) researcher *[wanted to retain corporate anonymity]*
Diarmuid O'Brien	Executive Director Centre for Research on Adaptive Nanostructures and Nanodevices (CRANN), Trinity College Dublin Ex-industry (Deerac Fluidics, Xoliox, NTERA)
Roger Whatmore	Previously Director of the Tyndall Centre, Ireland Research management and material science consultant Ex-industry (Plessey, GEC Marconi, UK)
Killian O'Driscoll	Director of Projects, National Institute for Bioprocessing Research & Training Ex-industry (Ericsson, Microsoft EOC)

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