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Strengthening Ireland's Market Focused Research Centre Landscape

Roadmap for the further development of market-focused research centres in Ireland

An independent report for the Department of Jobs, Enterprise and Innovation

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An independent report for the Department of Jobs, Enterprise and Innovation

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Table of Contents

Management Summary 8

The Department of Jobs, Enterprise and Innovation (DJEI) appointed Technopolis Group to assess further opportunities to strengthen market-focused research centre capacity in Ireland. 8

Irish public and private expenditure into research centres per inhabitant is slightly below that in comparator countries 8

Irish market-focused research centres have a different role in the Irish system than overseas centres in their respective systems in five important dimensions 9

There is a very substantial demand for middle TRL research, and for short-term applied and contract research in Ireland. The market-oriented centres assessed have <2% market share 10

There are six key requirements for a future-proof Irish market-focused research centre landscape 10

The Roadmap for the Medium Term Development of Market-Focused Research Centres in Ireland should focus on 3 Centre models: a strengthened Technology Centre Model and evolution towards a broader RTO Model, (implemented through a pilot approach), as well as the SFI Research Centre Model 12

Acknowledgements 13

1. Introduction 14

1.1 The purpose of this project 14

1.1.1 The background of this project in general 14

1.1.2 The added value of RTOs 15

1.1.3 DJEI's question to Technopolis Group 15

1.2 Methods used by Technopolis Group 16

1.2.1 Specific scope for the analyses in Ireland 16

1.2.2 Methods used for data collection in Ireland 17

1.2.3 Specific scope for analyses of overseas models 18

1.3 Structure of this Report 18

1.4 Important definitions 19

2. The Irish market-focused research centre landscape from 2004 to 2015 20

2.1 Policy developments in the Irish market-focused research landscape from 2004 to 2012 20

2.2 The Irish research landscape at the time of the ACSTI report in early 2012 22

2.3 Recent developments in the Irish Research Centre Landscape 25

2.3.1 Post-2012 developments within SFI that affect the Irish Research Centre Landscape 25

2.3.2 Post-2012 developments within EI/IDA that affect the Irish Research Centre Landscape 26

2.4 The Irish enterprise base at the beginning of 2015 28

3. Growth and ambitions for 2025 29

4. The current state of Ireland's market-focused research capacity 32

4.1 Investments in Ireland: total R&D expenditure (GERD) by type of R&D activity in Ireland compared with several other countries 34

4.2 Industry participation in the Irish centres: size and industry contributions of Irish centres compared with some overseas comparators 35

4.3 Closeness-to-market uptake of research conducted in the Irish research centres: the current state-funded portfolios of the Irish centres in terms of Technology Readiness Levels (TRLs) 36

4.4 Closeness to market uptake of research conducted in the Irish research centres (2016): centre directors' expectations on 2016 TRL distributions. 39

4.5 Specific research functions: the research activities that the centres undertake 41

5. Demand side: what research capacity does industry in Ireland need? 44

5.1 Destination of external RDI expenditures from industry in Ireland 46

5.2 RDI expenditure across TRL levels and research functions by industry in Ireland 48

5.3 RDI expenditure across sectors and priority areas by industry in Ireland 48

5.4 Opportunities for research centres 1: Integral analysis of supply and demand 51

5.5 Opportunities for research centres 2: Assessment of any unmet demand for market-oriented research capacity in Ireland 54

6. Inspiration from overseas: features of competitive market-focused elements of research landscapes internationally 57

6.1 Introduction to the four overseas market-focused research centres used in this section for a more detailed comparison 58

6.1.1 The presence of research centres Ireland and the four comparator countries 58

6.1.2 Macro-level comparisons of Ireland and the four comparator countries 60

6.1.3 IMEC in Belgium 61

6.1.4 The Fraunhofer Institutes in Germany 63

6.1.5 The Competence Centre Schemes in Sweden 65

6.1.6 The Catapult Centres in the UK 66

6.1.7 Preliminary success factors as identified overseas 68

6.2 Closeness to market uptake of research conducted in a broad set of overseas centres: the state-funded portfolios of the overseas centres in terms Technology Readiness Levels (TRLs) 68

6.3 Specific research functions: The research activities that overseas centres undertake 70

6.4 Organisational characteristics and ecosystem characteristics of overseas research organisations 71

7. Synthesis of the current state, key requirements for the future, and possible models and arrangements to meet the requirements 73

7.1 Summary of current state of Ireland's market-focused research capacity (Chapter 4) and the inspirations from overseas (Chapter 6) 73

7.2 Six key requirements of the future Irish research centre system 74

7.3 Introduction of four measures that potentially facilitate the requirements identified 76

8. Elaboration of the four selected measures 79

8.1 Measure 1: Baseline model 79

8.1.1 Implications of this measure for the research centre system 79

8.1.2 Assessment of meeting the future requirements 80

8.2 Measure 2: Strengthening the Technology Centres 81

8.2.1 Implications of this measure on the research centre system 81

8.2.2 Corresponding research centre model 82

8.2.3 Key transition steps 85

8.2.4 Implications for the rest of the Irish research centre system 86

8.2.5 Assessment of meeting the future requirements 86

8.2.6 Summary 87

8.3 Measure 3: Introduction of Demonstration and Deployment Centres 87

8.3.1 Implications of this measure on the research centre system 87

8.3.2 Corresponding research centre model 88

8.3.3 Key transition steps 90

8.3.4 Implications for the rest of the Irish research centre system 90

8.3.5 Assessment of meeting the future requirements 90

8.3.6 Summary 91

8.4 Measure 4: Development towards a broad RTO model 92

8.4.1 Implications of this measure on the research centre system 92

8.4.2 Corresponding research centre model 93

8.4.3 Key transition steps 98

8.4.4 Implications for the rest of the Irish research centre system 99

8.4.5 Assessment of meeting the future requirements 100

8.4.6 Summary 100

8.5 Measure summary table 101

9. Roadmap for the development of a competitive market-focused research centre landscape in Ireland 102

9.1 The measures that Ireland needs and that would fill the main gaps 102

9.1.1 Conclusions on measure suitability 102

9.2 The added value of combining a broad RTO model with strengthening the Technology Centres 103

9.2.1 Evolution towards a broad RTO model 103

9.2.2 The underlying strengthening of the Technology Centres 105

9.3 Implications for the Irish research centre landscape 105

9.3.1 The underlying strengthening of the Technology Centres 105

9.3.2 The implementation of the RTO model 106

9.4 The roles that key stakeholders would need to take to make this succeed 107
9.5 Pilot area for the implementation of the Roadmap 108
9.6 Timeline with actions, and transition steps to be taken by the relevant stakeholders 109
9.6.1 The Irish Research Centre Landscape that can meet the needs identified in Chapter 3 and Chapter 5 109
9.6.2 Introduction to the steps towards this landscape 109
9.6.3 Stage 1: steps to be taken in the first year 111
9.6.4 Stage 2: steps to be taken in the years 2-4 112
9.6.5 Stage 3: steps to be taken in the years 4 and 5 113
Appendix A List of those consulted 114
Appendix B TRL distributions for each of the Priority Areas 115

Table of Figures

Figure 1 ACSTI's 2012 recommendation on market-oriented research in Ireland..... 14

Figure 2 OECD's 2013 recommendations on RTO-like research centres in Ireland ... 14

Figure 3 Qualitative and quantitative sources used for assessing the situation in Ireland.....17

Figure 4 Definitions used in this project..... 19

Figure 5 Visualisation of the Irish research centre landscape in 2012..... 23

Figure 6 OECD's 2013 recommendations on RTO-like research centres in Ireland ... 24

Figure 7 Average industry contribution per researcher in Ireland vis-à-vis 29 other countries (2012 figures, in 1,000US$ per researcher) 24

Figure 8. Relative performance of Ireland's science and innovation system..... 28

Figure 9 Longer term ambitions of various stakeholders for the upcoming years 29

Figure 10 Components of the assessment of the market-focused research centre landscape in Ireland and the main findings per component..... 32

Figure 11 Total of public and private RDI expenditures (GERD) per inhabitant by type of RDI activity for several countries (2008-2012 averages)..... 34

Figure 12 Annual budgets of Irish research centres per capita compared with selected overseas centres (public core funding and private funding, no competitive funding) . 36

Figure 13 Explanation of the Technology Readiness Levels (TRLs) scale 37

Figure 14 2014 core funding portfolios of the Irish state-funded centres in terms of TRLs.....38

Figure 15 Expected 2016 core funding portfolios of the Irish state-funded centres in terms of TRLs 39

Figure 16 Centre activities in 2013 vis-à-vis 2016 in terms of TRLs (aggregated based on core funding per annum * €1,000; prognoses by the directors of the respective centres) 40

Figure 17 Research functions for industry, self-assessments of priorities per (group of) organisation(s) (reference year: 2014)..... 41

Figure 18 Research functions for industry, distributions of resources per organisation 42

Figure 19 The two main perspectives used to assess the needs of industry in Ireland in terms of research capacity and the extent to which this is currently offered..... 44

Figure 20 Components of the assessment of the needs of industry in Ireland in terms of research capacity and the extent to which this is currently offered 45

Figure 21 RDI expenditure by Irish companies 46

Figure 22 Destination of external expenditure (% of responding companies) 47

Figure 23 Private RDI spending across TRL categories by Irish based companies (2013).....48

Figure 24 RDI outsourcing by sector-15 49

Figure 25 External expenditure by research function, by sector..... 49

Figure 26 External expenditure by research function, by priority area 50

Figure 27 RDI Outsourcing by TRL, supply & demand (absolute figures *1000) 51

Figure 28 RDI outsourcing & public investment by research function (in €m, 2013).52
Figure 29 Supply/demand by priority area 53
Figure 30 Perceptions of Irish industry on the market-oriented research capacity in 2014 54
Figure 31 Recurring issues in the open responses 55
Figure 32 Main findings on the market-focused research capacity overseas.....57
Figure 33 Research centres Ireland and the four comparator countries.....59
Figure 34 Historical trend data on GERD; GOVERD; BERD; and HERD 60
Figure 35 Estimates of allocation of resources to groups of TRLs in Irish centres and in market-focused research centres and research centres in other countries (estimates) 69
Figure 36 The view of EARTO on RTO activities on the respective TRL levels 69
Figure 37 Research functions for industry, expert-assessments of priorities per (group of) organisation(s) (reference year: 2014) 70
Figure 38 Organisational characteristics and ecosystem characteristics of overseas research organisations 71
Figure 39 Current market-focused research centres system in Ireland (based on 2012 ACSTI and 2015 Technopolis findings).....76
Figure 40 Possible models and governance arrangements that could facilitate the four requirements identified 77
Figure 41 Introduction of four concrete measures that might facilitate the four requirements identified 78
Figure 42 Visualisation of Measure 1 (Baseline model)..... 80
Figure 43 Visualisation of Measure 2 (Strengthened Technology Centres)..... 82
Figure 44 Primary characteristics of Measure 2 84
Figure 45 Secondary characteristics of Measure 2.....85
Figure 46 Key implications of the introduction Measure 2 86
Figure 47 Key advantages and disadvantages of Measure 2 87
Figure 48 Visualisation of Measure 3 (Demonstration & Deployment Centres) 87
Figure 49 Primary characteristics of Measure 3 89
Figure 50 Secondary characteristics of Measure 3..... 89
Figure 51 Key implications of the introduction of Measure 3..... 90
Figure 52 Key advantages and disadvantages of Measure 3 91
Figure 53 Visualisation of Measure 4 (Broad Research & Technology Organisation in stage #1) 93
Figure 54 Visualisation of Measure 4 (Broad Research & Technology Organisation in stage #2).....93
Figure 55 Primary characteristics of Measure 4.....97
Figure 56 Secondary characteristics of Measure 4..... 98
Figure 57 Implications of the introduction Measure 4 99
Figure 58 Key advantages and disadvantages of Measure 4.....100
Figure 59 High-potential thematic areas for setting up an RTO 108

Figure 60 Outlines proposed evolution of the Research Centre Landscape to 2020 .110
Figure 61 Transition steps to be taken within the next year regarding the evolution of centres..... 111
Figure 62 Transition steps to be taken in years 2 to 4.....112
Figure 63 Transition steps to be taken in years 4 and 5.....113
Figure 64 Centre capacity (Primary capacity per Research Priority Areas) 115
Figure 65 Centre capacity (Supporting capacity per Research Priority Areas).....115
Figure 66 Centre capacity (Underpinning capacity per Research Priority Areas).....116

Management Summary

The Department of Jobs, Enterprise and Innovation (DJEI) appointed Technopolis Group to assess further opportunities to strengthen market-focused research centre capacity in Ireland.

At the beginning of 2015, Ireland's market-focused research centre landscape consists of twelve SFI Research Centres, fifteen EI/IDA Technology Centres, and a group of sector-specific centres, more specifically Teagasc (agriculture & food research), Tyndall Institute (information and communications technology research) and NIBRT (bioprocessing research and training).

DJEI found that it was timely to consider the country's research centre landscape to ensure that Ireland has an appropriate translational capacity to bridge research and technology commercialisation now and into the future and that enterprise in Ireland has access to the necessary research infrastructure, capability and services to support research based innovation.

The report at hand is the main output of this study. The report builds on the recommendations of the 2012 ACSTI report (*Sustainability of Research Centres*) and the 2013 OECD Report (*From Bricks to Brains*) that opportunities exist to further develop the research landscape in order to fully exploit the commercial opportunities emanating from research. The report also builds on both the increasingly acknowledged recognition that Ireland can only excel in a number of fields of research, and – as reflected by the Research Prioritisation Steering Group – must play to its strengths.

The project was made operational and demarcated in (1) the Technopolis proposal, which was accepted by DJEI at the end of June 2014; (2) the Project Plan, which was approved by DJEI on 15 September 2014; and (3) the Comparator Model Approach approved by DJEI on 15 October 2014. The project focused primarily on EI/IDA Technology Centres and on SFI Research Centres.

We are grateful for the intensive cooperation that we have had with various stakeholders, including the Department of Jobs, Enterprise, and Innovation (DJEI) Science Foundation Ireland (SFI), Enterprise Ireland (EI), IDA Ireland, the Irish University Association (IUA), the Institutes of Technology Ireland (IoTI), and various centre directors and industry representatives.

The details are presented in Chapter 1.

Irish public and private expenditure into research centres per inhabitant is slightly below that in comparator countries

Total R&D expenditure (GERD) in basic research, applied research, and to a lesser extent experimental development, is lower than in important comparator countries, such as the UK, the Netherlands, France, Denmark, Belgium, Austria, Germany, Sweden, Finland, and the EU and OECD averages. It is slightly above Russia, Portugal and Spain.[1] In particular basic and applied research expenditures per inhabitant are relatively low in Ireland. The public share of these investments is small compared with most EU countries and can be compared with the shares in e.g. Latvia and Italy. The large majority of R&D in Ireland is carried out by industry (cf. Chapter 5).

[1] Cf. https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm

It is clear that the number of market-focused research centres in Ireland has increased in the past three years. This has resulted in a very large number of centres that are of limited scale. Individual centres have invested in increasing their market orientation and their engagement with industry in Ireland and abroad. Yet, Irish state-funded market-focused research centres still have a large share of public core funding (and a relatively smaller industry cash contribution in absolute terms) compared with market-focused research centres in several countries of comparable size.

Despite the efforts of the SFI Research Centres, and the EI/IDA Technology Centres in the past two years, much of the research funded by industry still seems to be performed either in-house or overseas.

The details are presented in Sections 4.1 and 4.2 and in Chapter 5.

Irish market-focused research centres have a different role in the Irish system than overseas centres in their respective systems in five important dimensions

The Irish market-focused research centres – apart from Tyndall, NIBRT, and Teagasc – differ significantly from overseas market-focused research centres in five aspects.

In the first place, the bulk of Irish market-focused research centre capacity is delivered by a very large group of SFI and EI/IDA centres. This allows for good coverage of the Research Priority Areas. At the same time all individual centres are smaller compared with market-focused research centres in the overseas countries that we used for comparison.[2] SFI Research Centres and EI/IDA Technology centres lack economies of scale of overseas centres, which in Ireland can only be reached by Tyndall and Teagasc.

In the second place most overseas market-focused research centres, although connections with universities are crucial for them, operate independently from HEIs, which allows overseas market-focused research centres to invest in their own infrastructure and equipment, and to employ and incentivise their own staff. It allows them a certain degree of operational flexibility that overseas industry and SMEs appreciate. The most important metrics for career advancement of individual researchers are generally linked to industry engagement as opposed to more academic KPIs of publications etc.

Thirdly, most overseas centres have public funding horizons that are significantly longer than the 5 or 6 years plus potentially a short extension that the centres in Ireland have. This allows them to set up long-term investment plans, and offer sustainable career perspectives (and tenure tracks) to promising researchers. The Irish centres lack this perspective, as these centres cannot act outside the employment framework, which governs the HEIs.

In the fourth place, the centres in Ireland at the aggregated level focus on the low TRL levels (<4). Irish companies needing research and development that is more mature than TRL5 depend on the small EI/IDA Technology Centres' and Technology Gateway capacity, and on sector oriented research capacities in Teagasc, Tyndall, and NIBRT. Characteristics of research staff, KPIs (short term as well as long term), staff incentives, and research infrastructures for staff that work in SFI Research Centres (and thus are hired by universities) look more like those in overseas universities than those in overseas market-focused research centres. The EI/IDA Technology Centres themselves operate relatively close to market and they have TRL distributions that are more in line with those in the Fraunhofer Institutes and (to some extent) the Belgian Strategic Research Centres (SOCs).

[2] We have compared with centres in Belgium; Germany; Sweden; UK; The Netherlands; Denmark; Finland

Yet, they are considerably smaller than the SOCs and like the SFI Research Centres, and, unlike the SOCs and the Fraunhofer Institutes, they are predominantly dependent on university staff, research infrastructures and facilities.

In the fifth place, the Irish market-focused centres perform different functions from market-focused research centres in other countries. Unlike overseas comparators, centres in Ireland spend only small portions of their resources on typical near-market-focused R&D and services such as consultancy, contract research services, and short-term applied research. Overseas market-focused research centres spend relatively more resources on short-term applied contract research, as well as on contract research services, than the EI/IDA Technology Centres and SFI centres and the sector-oriented centres in Ireland. This function is less developed in the Irish system of EI and SFI centres and the sector-oriented centres, as many of them primarily focus on collaborative research.

The details are presented in Sections 4.3 to 4.5 and in Chapter 6.

There is a very substantial demand for middle TRL research, and for short-term applied and contract research in Ireland. The market-oriented centres assessed have <2% market share

There is a large market for the provision of external RDI services to Irish companies, expected to grow to over €1bn in 2018, especially in upper-middle and high TRL areas and short-term applied and contract research.

The current market-oriented research centres are strongest in medium-term collaborative research where they have their highest market shares (±10%). Market shares in short-term applied and contract research are currently very small (<2%). This is not surprising, as, for example, the SFI Research Centres and the EI/IDA Technology Centres were set up to perform primarily collaborative research.

There is a concrete demand or market opportunity for the supply of more short-term applied and contract research, specifically in the sectors of Chemicals (Pharmaceuticals), Computers, Electronic and optical products and Medical Devices, and in terms of priority areas specifically ICT, Medical Devices and Manufacturing Technology (including process technology) areas.

The details are presented in Chapter 5.

There are six key requirements for a future-proof Irish market-focused research centre landscape

Despite the young age of substantial investments in the system, the ambitions for the next decade in terms of market-focused research are clear. Ireland needs appropriate translational capacity to bridge research and technology commercialisation and needs to provide Irish enterprise with access to capability and infrastructure to support research and innovation activities now and into the future. This implies that in the next decade, it is inevitable to further increase the competitiveness of its market-focused research centre landscape.

Our Expert and Stakeholder Workshops and our interviews show that the efforts by agencies in supporting the establishment and growth of the centres in the past three years have been impressive. But they also show that policymakers in Ireland should be aware that a future-proof market-focused research centre landscape in Ireland should address six key requirements that – despite these efforts – are still less well developed.

Requirements 1 to 3 (based on the needs of industry in Ireland)

The first three requirements concern the need for more research centre capacity at the middle TRL level, the need for more research centre capacity at the high TRL level, and the need to offer new (RTO) research functions to industry in Ireland.

Firstly, there is a need to offer (more) middle TRL research capacity in line with needs of (Irish-based) industry. This is clearly shown in Sections 4.3; 4.4; and 6.2. Although the Irish system is unique and requires tailor-made solutions, inspiring models might include the big Fraunhofer/SOC (IMEC) centres that cover a broad range of TRLs with critical mass; and the applied Competence Centres that focus on the middle and higher TRLs (validations, demonstrations, and beyond).

Secondly, there is a need to offer (more) higher TRL research capacity with critical mass in line with needs of (Irish-based) industry. At this point in time, industry in Ireland is not well served at these levels. Unlike Ireland, many overseas systems have RTO-like organisations that meet the requirements of industry at these levels. Again, key evidence for this need can be found in Sections 4.3; 4.4; and 6.2.

Thirdly, the system should allow for more short-term applied research, and contract research services (validation, testing, and certification) than is offered by the current set of market-oriented research centres. Irish research centres as a group allocate most of their resources to medium and short-term problem oriented research. This is clearly shown in Section 4.5. There is no doubt that these functions serve many companies in Ireland, as the budget figures clearly show. Yet there are clear differences with what Ireland needs in terms of research functions (see Section 4.6). Industry makes it very clear that it needs a broader offering of research functions in addition to those currently on offer.

Requirement 4 (based on inspirations from overseas)

The fourth requirement concerns the need for more operational flexibility for the market-oriented research centres in Ireland while respecting the National Strategy for Higher Education, and to maximise the return on investment made in the higher education system in the past years. This implies that an increased number of market-oriented research centres should be allowed to invest in their own capital goods, to set up their own employment statutes, and to rely on a long-term funding horizon. In addition to that, the future centres must have peer-to-peer relations with HEIs, that might be compared to what NIBRT and to some extent Tyndall have in Ireland. This implies working together on shared goals such as increasing the outputs of education & training in the STEM fields, making Ireland more successful in Horizon 2020, and co-investing in research infrastructures. Centres that were analysed in The Netherlands, Denmark, and Finland, all have a clear organisational distance to HEIs that might be compared to what Teagasc has in Ireland. This operational flexibility benefits the HEIs, and it is crucial for any centre that has the ambition to receive up to 1/3 of its funding in cash from industry and that wants to meet requirements 1 to 3.

Requirements 5 and 6 (based on the positions of the main stakeholders in the Irish STI system)

The fifth and the sixth requirements concern the need for more market-focus type activity in research centres in Ireland, and to build on existing strengths when implementing change in the system, respectively.

The need for increased market orientation is the fifth requirement of the future system. A key requirement of the future system should be that the market-oriented research centres in it can ‘take along’ the Irish-owned industry. Taking along industry was perhaps more difficult during the early 2000s when there was significant increase in public R&D spend while many were only beginning on their ‘R&D journeys’. Section 5 shows that there are significant opportunities from a demand-side perspective. The details are presented in Chapter 3, Chapter 7, and Chapter 8.

The sixth requirement concerns the need to build on existing strengths. All are aware of the Irish needs to build on the current strengths of the system. Any measure implemented should be based on existing strengths and capitalise on the substantial investments made in the Irish research centre system up to this moment.

The Roadmap for the Medium Term Development of Market-Focused Research Centres in Ireland should focus on 3 Centre models: a strengthened Technology Centre Model and evolution towards a broader RTO Model, (implemented through a pilot approach), as well as the SFI Research Centre Model

The overall conclusion of the review is that there is currently unmet demand for the provision of external RDI services to Irish based companies, especially in more applied research areas and in upper-middle and high Technology Readiness Levels (TRL) and in short-term applied and contract research and that for an internationally competitive research ecosystem for the future, Ireland should begin to build capacity in these areas through evolving and strengthening the existing research centre base.

It is proposed that the market focused research centre landscape should evolve and introduce a third model on a pilot basis:

- SFI Research Centres (RCs). These centres should continue on their existing trajectory, continuing to build strategic linkages with enterprise at the TRL1-4. The RC's main focus will continue to be on oriented basic and short and medium term problem driven research, academic led and industry informed, with industry influence achieved through collaborative research projects, funded through both the Centre and the Spokes funding programmes.
- Strengthened Technology Centres (TCs). Technology Centres should evolve towards a consolidation into fewer centres with increased critical mass, (including infrastructure/facilities/equipment where required) focused on industry led research in the TRL 4-7 range, with increasing capacity to deliver a broader range of research functions.
- A broad adapted RTO Model. Building on current capacity and expertise, existing SFI Research Centres and EI/ IDA Technology Centres, could feasibly transition towards a broad adapted and flexible RTO model. These centres would deliver research across TRL 2-8 with emphasis on mid to high TRLs and RTO functions, including technology validation and testing services, pilot lines in the case of manufacturing research, contract research services and consultancy.

Commitment to growth in the HEI research base (via SFI Research Centres, individual PI awards and infrastructure investments) is critical to the ongoing competitiveness of the research ecosystem and Ireland's reputation internationally and implicitly underpins recommendations for future development of the market focused research centre landscape proposed.

The three models outlined above, in combination, provide a framework for the industry facing research centre landscape in Ireland to evolve and develop further in line with enterprise needs and the opportunity to do so in a manner that builds on strengths developed over the past 10-15 years. Together these models can provide a comprehensive and coherent portfolio of research capacity across the entire TRL scale and deliver the range of research functions offered to industry in leading market focused research ecosystems internationally.

Specifically, further development of the EI/IDA Technology Centre model, combined with the evolution of centres towards a broader RTO model provides a mechanism to meet the six requirements identified through the analysis presented. It provides the structures to substantially strengthen the current offering of middle TRLs; strengthen the high TRLs offer; and provide an improved supply of short-term applied research capacity, as well as more contract research services capacity for industry and SMEs in Ireland.

Features such as flexibility and adaptability should be retained in the strengthened Technology Centre and broad RTO models to allow evolution of the research centre landscape to be both opportunity driven and demand led and to build on existing strengths. Evolution of market-oriented centres between models and consolidation of synergistic research activity should be encouraged. Inter-centre and inter-model interaction should also be encouraged.

Neither the RTO model, nor the strengthened Technology Centre model should be a 'one size fits all'. Characteristics will depend on the structure and needs of the enterprise base it is serving. Furthermore, the mix of centres in a given technology platform, sector or research priority area may vary and evolve over time. Therefore, a suite of RTO's and strengthened Technology Centres may emerge over time with differing characteristics (in particular with respect to capital investment). While governance models for different RTOs should be broadly similar, some flexibility on governance models should be allowed to ensure success.

It is proposed that evolution towards a broad adapted RTO model be achieved in an evolutionary manner and be introduced through a pilot initiative to gain an understanding of how such capacity might be built in Ireland. Learnings and experiences in a pilot initiative would be then brought to bear on potential further development of higher TRL research capacity and broader research functions serving a wider cross section of Irish industry.

A number of potential thematic areas with substantial demand for RTO capacity were identified for consideration as areas for a potential pilot initiative. These areas are:

- Computer, Electronic and optical products;
- Manufacturing Technology / Process technology;
- Chemicals / Pharmaceuticals Manufacturing;
- Medical Devices.

Also a number of existing centres with potential to evolve towards a broader RTO model to deliver a broader research span and range of functions were identified. These include Tyndall National Institute, ICMR and NIBRT.

Section 9.6 presents a timeline with actions to be taken by the relevant stakeholders to successfully implement the Roadmap. We recommend starting the implementation process in August 2015.

The details are presented in Chapter 9.

Acknowledgements

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1. Introduction

1.1 The purpose of this project

1.1.1 The background of this project in general

In 2011, the Advisory Council on Science, Technology and Innovation (ACSTI) appointed a Task Force to map the Irish research centre landscape. The study was supported by DJEI and was published in 2012. One of its main conclusions was that 'a gap exists in the current State-supported research centre landscape that needs to be addressed in order to fully support the commercial opportunities emanating from research'.[3]

Parallel to that the recognition that a country of Ireland's size can only excel in a limited number of fields of research was increasingly acknowledged. The report of the *Research Prioritisation Steering Group*, formally adopted by Government in 2012, aims to accelerate the delivery of economic outcomes from Government investment in public research organisations by aligning the majority of future public investment of research funders with 14 priority areas.

In addition a growing consensus developed that it was timely to consider the country's research centre landscape to ensure that Ireland would have an appropriate translational capacity to bridge innovation in research with commercialisation. It was found important to provide Irish enterprise with access to capability and infrastructure to support research and innovation activities now and in 2025. The ACSTI stated the following.

Figure 1 ACSTI's 2012 recommendation on market-oriented research in Ireland

> Research and Technology Organisation (RTO) capacity should be developed within the landscape, in synchronisation with and actively supporting the maturing capability and capacity in particular of the Irish-owned company base to engage in external applied R&D.

Source: Advisory Council for Science, Technology, and Innovation (2012). *Sustainability of Research Centres*. Forfás.

One year later, the OECD drew similar conclusions when it stated the following.

Figure 2 OECD's 2013 recommendations on RTO-like research centres in Ireland

> Although the centre landscape is evolving, it does not seem that the gap is being filled in Ireland. The new larger SFI Research Centres (merging CSETS and SRCs) fulfil a different and important role of longer-term strategic research and academic performance metrics remain dominant. Enterprise Ireland's new Technology Centres are industry rather than firm focused and their scale is relatively small and project based and therefore not likely to build the critical mass and continuity that an RTO can bring. The government should move to setting up a pilot RTO.

Source: OECD (2013). *From Bricks to Brains: Increasing the Contribution of Knowledge Based Capital to Growth in Irelan*d. OECD Economics Department Working Papers No. 1094

[3] Advisory Council for Science, Technology, and Innovation (2012). *Sustainability of Research Centres*. Forfás.

All should be aware that these recommendations were drafted in 2013 and that there have been developments since then. In 2015 the OECD highlighted again the need for such capacity in Ireland.[4]

1.1.2 The added value of RTOs

RTOs in Europe have functions that universities do not tackle.[5] Many are located on university campuses, which is regarded as a success factor. The other defining characteristic of RTOs is that they are at least in part state-financed and that they receive long-term funding. They perform tasks that cannot be done through market mechanisms. RTOs focus on generating applied knowledge and conducting R&D with and for industry. They may have a special task to support SMEs or low-capability firms. They focus on user- or problem-orientated research for the benefit of society and normally win the greater part of their funds competitively. Typically, their role is to assume some of the risks of industrial innovation, helping companies to go beyond what they would otherwise technically be able to do.[6] Their state subsidy distinguishes them from other contract research organisations such as technical consultancies. RTOs tend to operate with a three-stage innovation model:

1. Exploratory research and development to develop areas of capability or technology platforms;
2. Refining and exploiting that knowledge in relatively un-standardised ways, often in collaboration with industry;
3. More routine exploitation of the knowledge, including via consulting and services.

RTOs account for upwards of 40% of Europe's state-funded R&D.[7] Besides their impact at geographical level, RTOs' activities provide critical inputs for the advancement of the knowledge base, a critical input for commercially exploiting new ideas, and hence promote businesses and create employment.

1.1.3 DJEI's question to Technopolis Group

In May 2014 DJEI asked Technopolis Group to undertake a study aimed at identifying further opportunities to strengthen market-focused research capacity in Ireland. The project was made operational and demarcated in (1) the Technopolis proposal, which was accepted by DJEI end of June 2014; (2) the Project Plan, which was approved by DJEI on 15 September 2014; and (3) the Comparator Model Approach that was approved by DJEI on 15 October 2014.

The report at hand is the result of this 8-month project. One should be aware that this project did not take place in isolation. It builds on previous and ongoing policy processes in Ireland, and on insights from the Department of Jobs, Enterprise, and Innovation (DJEI), the ACSTI, the OECD, Science Foundation Ireland (SFI), Enterprise Ireland (EI), IDA Ireland and the Higher Education Association (HEA).

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[4] OECD (2015). ECONOMIC POLICY REFORMS 2015: GOING FOR GROWTH. OECD, pp. 220.

[5] See e.g. Arnold, E., Brown, N., Eriksson, A., Jansson, T., Muscio, A., NählinderNa̋hlinder, J. (2007). *The Role of Industrial Research Institutes in the National Innovation System*. Stockholm: VINNOVA.

[6] SörlinSőrlin, S., Arnold, E., Andersen, B., Honoré Honoré, J., Jørna, P., LeppävuoriLeppa̋vuori, E., et al. (2009). *A Step Beyond: International Evaluation of the GTS Institute System in Denmark*. Copenhagen: Forsknings- og innovasjonsstyrelsen

[7] ERAB. (2005). *Research and Technology Organisations (RTOs) and ERA*. Brussels: European Commission: European Research Advisory Board.

1.2 Methods used by Technopolis Group

The Call for Tenders of this project suggested the use of a number of methods. Prior to submission of the proposal, Technopolis and DJEI discussed the usefulness of alternative and additional methods. These were approved by the Advisory Group and made operational in the Project Plan approved on 15 September 2014. The report at hand follows the methodologies set out in the Project Plan devised to fully deliver on the terms of reference as outlined in the Request for Tenders.

1.2.1 Specific scope for the analyses in Ireland

The ACSTI recommended the use of the so-called *ACSTI categorisation* of research centres in further policy making in Ireland. This categorisation distinguished between four types of research centre, each having a different rationale for public support and therefore different objectives. This grouping was found necessary to distinguish at a high level the key role of the different research centres; that is to provide a categorisation of the centres and naming them, according to the ACSTI, would provide a more manageable language to discuss the characteristics of the State-supported research centre landscape.

The research centres on which the Roadmap at hand focuses, are the ACSTI Group 2 and Group 3 centres: Academic-Industry Centres and Industry-Focused Centres, respectively. Like the ACSTI report, the current study is focused on those centres supported directly by state funds for supporting research, and therefore it excludes HEI research centres funded indirectly by the HEA block grant and/or by an HEI's own funds.

This implies that this analysis of the market-focused element of the Irish research landscape includes:

- SFI Research Centres
- EI/IDA Technology Centres
- Tyndall National Institute
- NIBRT
- Teagasc

This implies that this project does takes other elements, such as the Technology Gateways, ICHEC, or the establishment of Technological Universities in Ireland into account, but it does not include an in-depth analysis of these developments. As we discuss capacity of the landscape, most data are presented at an aggregated level.

1.2.2 Methods used for data collection in Ireland

Our findings are based on a total of 18 sources. These are presented in the figure below.

Figure 3 Qualitative and quantitative sources used for assessing the situation in Ireland

Initially identified in the Request for Tenders and included in the Analyses by Technopolis Group	Added to the project by Technopolis Group
1. The Frontline report 'Technology Centres Programme: Interim Evaluation'. 2. The 2011/2012 ACSTI report on 'Sustainability of the Irish Research Centres'. 3. The SFI TRL summary for the SFI centres – document and spreadsheet. 4. The TI research centre mapping document, created on 29 April 2014. 5. Raw data collected from the Technology Centres, collected by Enterprise Ireland. 6. Paper from EI on the establishment of the RO which is a combination of the I2E2 and ICMR TC. 7. PAG work on research needs. 8. Previous surveys sent out by IDA Ireland	9. Surveys sent to all EI/IDA Technology Centre directors and SFI Research Centre directors, on activities performed in their centres, prognoses, and client bases.[8] Response rate: 95% of all centre directors. 10. Thirteen (group) interviews with key 18 stakeholders from relevant agencies, employers' organisations, research centres, and industry. 11. An electronic questionnaire sent to all Ireland-based RD&I performing enterprises to analyse demand-side expenditure patterns. See also Section 5. 12. One Expert Workshop with representatives from Ireland and from overseas to discuss our approach, and identify inspiring cases from overseas (23 September 2014). 13. Two Stakeholder Consultation Workshops attended by 59 stakeholders from industry, research, and government to validate findings from the mapping exercise, as well as the results from the comparator model case studies and possible lessons and alternative model and approaches for Ireland (17/18 November). 14. An electronic questionnaire distributed among the ABSEI RD&I performing population (total of 1708 firms in Ireland). In total we received 337 valid responses to our survey (response rate of ±20%). The survey was linked with ABSEI RDI expenditure data to be able to get insight into expenditure patterns in terms of actual monetary volumes. This provides a solid basis for analysing the patterns of the RDI demand side in Ireland, especially given the response rate was reasonably well distributed among different RDI-expenditure bands, Irish-owned and non-Irish owned firms. [9] 15. A large set of qualitative sources. 16. Analyses of ABSEI data. 17. Analyses of BERD data. 18. Analyses of Eurostat data. 19. Analyses of OECD data.

[8] The survey validation was designed together with EI (Martin Hussey) and SFI (Marion Boland). We are grateful for their suggestions and, and their approval of the survey structure. All suggestions from EI and SFI were implemented. The survey was sent out to centre directors by respectively EI and SFI, and was filled out by 95% of centre directors.

[9] We thank Mr. David Harmon of Insight Analytics for his support in sending out the surveys and cleaning the data.

1.2.3 Specific scope for analyses of overseas models

Analyses of overseas models serve two purposes: they help to identify missing or under-critical components in the Irish market-focused research landscape based on international best practice, and they offer inspiration. Comparator countries come in two modes. First, Technopolis identified a large set of countries for analysis.[10] The Advisory Group and DJEI selected a small sample of overseas countries to be used for more in-depth analyses, including an analysis of specific relevant research centres within these countries.[11]

We identified a total of 8 primary characteristics for the comparator model. These characteristics were identified as important issues in our interviews, and in the Expert Workshop.[12] We used these primary characteristics to select the comparator models for WP3. In addition, we identified a total of 43 secondary characteristics. We refer to them as secondary, as they are not used to select comparator models. They are however equally important in the analysis of the comparator models and in developing the proposed models for Ireland outlined later in the report.

Assessments of centres in overseas countries are based on desk research to analyse the situation in the respective research ecosystems. In addition, insights are based on the experiences and the knowledge of several of Technopolis' and external senior experts who were used to assess the situations in overseas countries and to see how overseas models and governance arrangements can inspire Ireland to strengthen the market-focused element of the Irish research landscape. Moreover, several additional interviews were conducted to provide a full overview of the situations abroad.

1.3 Structure of this Report

The next chapter presents the developments in the Irish market-focused research centre landscape between 2004 and 2015. This includes all relevant policy developments in the Irish market-focused research landscape between 2004 and 2012; an analysis of the Irish research centre landscape at the time of the ACSTI report in early 2012; and the OECD study on the market-focused research capacity one year later. It also includes an assessment of recent developments in the Irish research centre landscape and the current RDI performance of the Irish enterprise base at the beginning of 2015. Chapter 3 looks at the future and presents the ambitions for 2025.

Chapter 4 presents the current state of Ireland's market-focused research capacity in research centres. This includes an analysis of R&D investments in Ireland, and assessments of the resources available to the Irish research centres; the closeness to market uptake of research conducted in the Irish research centres; 2016 prognoses on this closeness to market and the specific research functions that the Irish centres offer to industry in Ireland and overseas. Chapter 6 looks at different models overseas and presents features of competitive market-focused elements of research landscapes internationally. Therefore four market-focused research centres are introduced that are analysed in more detail to offer inspiration to Ireland.

In Chapter 7 a synthesis of the current state is presented, and a number of key requirements for the future are presented. Also four models and governance arrangements to facilitate the requirements are proposed. Chapter 8 elaborates on these models and governance arrangements, including high-level implications for the current elements of the Irish research centre system.

The roadmap for further development of market-focused research centres in Ireland is presented in Chapter 9.

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[10] This set includes Belgium; Germany; Sweden; UK; The Netherlands; Denmark; Finland.

[11] Belgium (IMEC); Germany (Fraunhofer Institute); Sweden (Competence Centres); UK (Catapult Centres).

[12] We will use these dimensions to describe our recommendations

1.4 Important definitions

It is important to be aware of the following definitions. Individual agencies might use definitions that are slightly different from these. Those presented in Figure 4 are generally in line with the definitions used overseas and therefore contribute to our overseas comparison.

Figure 4 Definitions used in this project

Definiendum	Definition
Approach	The potential changes proposed to the existing status quo in Ireland (introduction of a model and consequences for existing centres, or change in one or more of the existing centre models).
Comparator Model	Detailed description of the modes of establishment of a new type of Centre covering the characteristics, including location, governance, funding, scale, scope, staffing, etc. There can be several comparator models.
Competence Centre	Joint academic-industry research centres focused on longer-term user-oriented basic research. The aim is to conduct high quality academic research oriented to applications and industry needs.[13]
Core funding	Either programme funding directed specifically at supporting a research centre or recurrent grant-in-aid funding for a research centre.[14]
HEI/university funding	The portion of the centre that is funded by the HEIs themselves. It typically reflects the salaries of the permanent HEI staff associated with the centres.
Public competitive funding	Project-base funding that a centre wins through competitive processes – either nationally or internationally. Important funders in this respect are e.g. SFI, and the Horizon 2020 programme
Research Centre	A well-defined group of staff and facilities (space and equipment) dedicated, in the main, to research in a particular domain over and above any other priorities. It encompasses research activities conducted within a range of different institutional settings and with a variety of research objectives. [15]
Private Sector funding	Funding raised from private entities (both for-profit and non-profit entities), and indicates cash contributions. Industry in-kind contributions are highlighted separately.
RDI	RDI refers to the whole process of generating new knowledge and turning it into productive economic activity and is slightly wider definition than R&D.
State-funded Centres	Centres supported directly by state funds directed specifically at supporting research centres and therefore excluding HEI research centres that are funded indirectly by the HEA block grant and/or by an HEI's own funds.
Roadmap	A description of required evolution of the market-focused element of the research centre landscape over the next decade with CSF and milestones outlined, i.e. an implementation strategy for the approach.
RTO	Extra-university research organisations which provide, as their predominant activity, research and development, technology and innovation services to enterprises, governments and other clients.

Source: Technopolis Group

[13] We note that in Ireland the term 'competence centre' is used for a different type of centre (smaller and focused on much more applied research). We do not refer to, or intend to refer to, this type of centre.

[14] Arnold, Erik et al. (2012). *Research Centres in Ireland: Funding Models, Oversight Mechanisms and Vision of a Future Research Centre Landscape* An independent report to Forfás by Technopolis Ltd

[15] It includes, for example, centres established in higher education institutes as a result of either institutional strategies or programmatic funding from public agencies (or both), standalone publicly-funded research institutes (such as IMEC in Belgium or the Max Planck and Fraunhofer Institutes in Germany), and government laboratories focused on research in support of the policy requirements of specific government departments. (Cf.: Technopolis Group (2012). *Research Centres in Ireland: Funding Models, Oversight Mechanisms and Vision of a Future Research Centre Landscape*.)

2. The Irish market-focused research centre landscape from 2004 to 2015

This chapter presents the policy developments in the Irish market-focused research landscape since 2004. It shows that, even though the Irish market-focused research landscape is still young of age, the various stakeholders have realised a significant growth in the past decade and are ambitious when it comes to the upcoming decade.

The findings in this chapter are based on an extensive literature review, on a large set of interviews with high-level representatives of the Departments, the relevant agencies, the HEIs, and industry and on inputs of the Expert Workshop and two Stakeholder Workshops.

One should be aware that a systematic review of the outputs as defined by TRL of recent investments of SFI and EI is presented in Chapter 4. However, the chapter at hand intimates that policy changes have not yet been so substantial as to fill the gaps identified by ACSTI and the OECD.

2.1 Policy developments in the Irish market-focused research landscape from 2004 to 2012

In July 2004 Forfás published *Building Ireland's Knowledge Economy*.[16] It stated that levels of linkages between enterprise and academia were low and a cause for concern. It also stated that Ireland should strongly support the development of strategic research competencies (technology platforms) based on enterprise needs; and that by 2010, Ireland should be 'internationally renowned for the excellence of its research and be at the forefront in generating and using new knowledge for economic and social progress, within an innovation driven culture'. This was re-emphasised in the *National Development Plan 2007–2013,*[17] where it stated that the development of a knowledge-based economy was 'one of the key challenges and opportunities facing Ireland', and that factors which have contributed to Ireland's economic success in the past decades would no longer be sufficient to sustain recent growth. In the years following, equally ambitious statements would be made by the Department of the Taoiseach, by DJEI, by EI, by IDA Ireland, and by SFI.[18]

The Department of the Taoiseach stated for instance in 2006 that 'Industry-led research needs to be supported by appropriate infrastructure and to this end support for the development of competence centres will be important in translating advanced research into commercialisable technology'.[19] In 2008 it noted that SFI 'will continue to build Ireland's world class research capacity in strategic areas allied to the needs of industry'.[20] That same year, DJEI stated that its goal was to 'strengthen links between Irish research infrastructures and industry and transferring knowledge to the marketplace remain key goals of Ireland's innovation strategy', and that 'enterprise-led Competence Centres are being set up with highly qualified researchers to undertake strategic market-focused R&D for the benefit of industry'.[21]

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[16] Forfás (2004). *Building Ireland's Knowledge Economy*.

[17] Government of Ireland (2007). *National Development Plan 2007-2013*.

[18] Cf. Hennessy, Philip (2011). The vision for Irish enterprise policy: knowledge too slippery to handle, in: *Administration*, Vol. 59, No. 3, pp. 1-25.

[19] Department of the Taoiseach (2006). *Strategy for Science, Technology and Innovation*. The Stationery Office.

[20] Department of the Taoiseach (2006). *Building Ireland's Smart Economy: A Framework for Sustainable Economic Renewal*. The Stationery Office.

[21] Department of Enterprise, Trade and Employment. (2008). *Innovation in Ireland*. The Stationery Office.

One year later, SFI stated that its target would be to 'initiate centres, institutes and teams that establish research links between Irish research institutions and industry, attract or substantially increase the RDI investments of at least 10 foreign-owned firms in Ireland and produce at least 5 significant research collaborations between research institutions and indigenous companies'.[22] The importance of these SFI centres for FDI purposes was clearly stressed by IDA Ireland.[23] Enterprise Ireland, at the same time, found that 'realising the commercial potential of Irish-based RDI is a major priority', and that its 'aim is to accelerate the commercialisation of research by stimulating and facilitating interaction between industry and the research infrastructure'.[24]

It is clear that the main ministries and agencies, including the Department of the Taoiseach, DJEI, EI, IDA Ireland, and SFI have been very clear about the importance of market-focused research centre capacity in the Irish STI landscape. Between 2004 and 2012 this resulted in the foundation of the semi-autonomous research institute Tyndall, and in the emergence of several research centre programmes. NIBRT was established in response to clear market demand for research and training in the area of biotech manufacturing.

Relatively substantial were SFI's investment in Centres for Science, Engineering and Technology (CSETs), funded €2m to €5m per year over a 5 year term (with the potential for a second 5 year term) and aimed to support industry to work with universities in areas of strategic importance to Ireland. The CSET programme was operational from 2003 and was a key component of SFI's support for academic research representing 20-25 per cent of its total annual investment in Irish higher education institutes.[25] Industry had to commit to participate and contribute funding (both in cash and kind). Ultimately, the ten centres developed formal partnerships with 57 organisations, 52 of which were businesses. The number of partners per centre varied between two and ten. The CSETs engaged with a further 116 industries under less formal 'collaborative' agreements compared with the formal partnership arrangements. Funding from SFI to the CSETs predominantly supported research staff, PhD training and research consumables. CSETs depended on existing research capabilities & infrastructure within HEIs, and were therefore often based within the larger Programme for Research in Third-Level Institutions (PRTLI) funded centres.

SFI's Strategic Research Clusters (SRC) aimed to facilitate the clustering of researchers to carry out joint research activities in areas of strategic importance to Ireland, whilst also providing time and resources to attract and cultivate industry partnerships that could inform and enhance their research. Whilst they had certain similarities (most evidently, to foster industry-academia collaboration), the CSET and SRC programme differed in terms of scale, scope and duration. SRC awards ranged from €500,000 to €1,500,000 (direct costs) per year over the five (3+2) year period

The Competence Centres programme was launched in 2007 by Enterprise Ireland in response to the *Strategy for Science, Technology and Innovation* (2006-2013) of the Irish Government. The Competence Centres were later succeeded by the EI/IDA Technology Centres programme. The key aim was to build critical mass in research areas where there did exist industrial and academic expertise.[26]

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[22] SFI (2009). *Powering the Smart Economy: Science Foundation Ireland Strategy 2009-2013.*

[23] IDA Ireland (2008). *Annual Report.*

[24] Enterprise Ireland (2006). *Annual Report & Accounts 2006 Transforming Irish Industry.*

[25] Technopolis Group (2012). *Evaluation of the Centres for Science, Engineering & Technology Programme.* Final Report to Forfás.

[26] Frontline Consultants (2014). *Technology Centres Programme Interim Evaluation Report.* Final Report to Enterprise Ireland.

The focus of the centres would be on market focused research with industrial market potential driving the research agenda.[27] The centres (2007) were to have a physical focus and up to €2m in funding per annum to guarantee critical mass, however budget constraints imposed in 2008 reduced the operational budget to €1m per centre per year by EI/IDA for 5 to 8 years. Compared with the previously identified centres, both the Competence Centres and their successors (Technology Centres) were very much industry focused. Enterprise Ireland and industry together identify fields of applied research of interest to businesses in Ireland. In addition, Technology Centres are the primary ones in Ireland that are fully industry led. Industry set the overall remit of the centre and leads the day-to-day activities. They are also focused more exclusively on industry relevant, commercialisable research than the majority of other Irish research centres. [28] In the run-up to the 2012 ACSTI report, the majority of EI/IDA Technology Centres were based within HEIs or research institutes, which allowed for access to high quality researchers and facilities. Only a few were based in private entities outside HEI structures.

Besides the Technology Centres, Enterprise Ireland also funded the Applied Research Enhancement Centres (ARE Centres) programme. This was set up by Enterprise Ireland in 2004 to enhance the applied research capabilities within Ireland's Institutes of Technology (IoTs). The ARE Centres were set up to enable regional development by introducing innovative technological solutions through collaboration with industrial partners, and to develop the next generation technology platforms for the benefit of Irish-based industry through a dedicated applied research strategy. They received centre funding of between €300,000 and €500,000 per year for four years.

2.2 The Irish research landscape at the time of the ACSTI report in early 2012

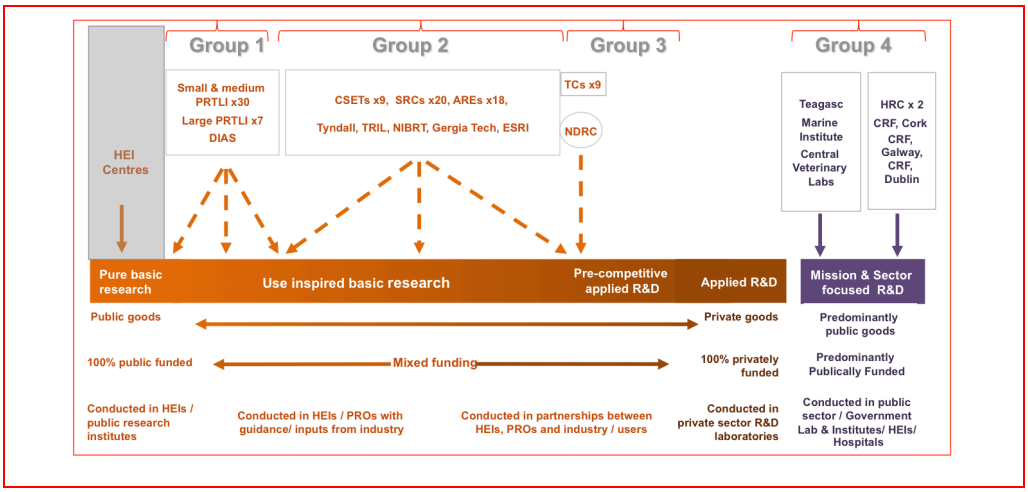
In June 2012, the ACSTI presented its report on 'Sustainability of Research Centres'. The aim was to address the current and future mix, and profile of the Irish research centre portfolio and the potential funding models that may be best suited for sustaining research centres. The ACSTI concluded that the portfolio of research centres has evolved rapidly over the past decade through significant funding by several government departments, agencies and the HEIs.

The ACSTI concluded that that the majority of the research centres were based within HEIs. Most of the centres in Ireland, according to ACSTI, were small or medium in size, which again reflected the funding levels available from the various funding programmes. The ACSTI presented Figure 5 as a clear representation of the Irish research centre landscape at the beginning of 2012.

[27] Competence Centres Model Document, Technology Leaders Hosting Guidelines.

[28] Frontline Consultants (2014). *Technology Centres Programme Interim Evaluation Report*. Final Report to Enterprise Ireland.

Figure 5 Visualisation of the Irish research centre landscape in 2012



Source: Technopolis Group

The ACSTI concluded that the centres cover a large proportion of the TRL scale except for the area focused on pre-competitive R&D and the area focused on more applied research, which was only partially covered by NDRC and the EI IDA Technology Centres, Tyndall, NIBRT, and Teagasc. This implied there was a lack of applied research capacity in Ireland directed at medium term industry needs as well as shorter-term technology development and technical services for industrial clients. The ACSTI referred to these centres as industry-focused centres, and more specifically as Research and Technology Organisations (RTOs).

The Council therefore recommended that the funding budget for research centres should be refocused to ensure appropriate critical mass, skill balance and equipment within a smaller number of research centres than existed at the time, and to re-divert some funding towards resolving centre sustainability issues and the development of new centres.

Moreover, it concluded that to fill an apparent gap in the Irish spectrum of research centres (the Group 3 gap), a funding scheme be initiated to support the evolution of some existing Group 2 and current Group 3 centres and/or the introduction of new centres, with a view to developing a small number of RTOs in the Irish research centre landscape.

The OECD drew similar conclusions one year later.[29] The OECD concluded that, while attracting high-tech multinationals should remain central in Ireland's strategy, the establishment of applied research centres should be promoted, to better develop spill overs between these firms and domestic SMEs. According to the OECD this would require applied research centres with critical mass, and 'more autonomy over employment and salary conditions in certain defined cases'.[30]

In parallel with that, the OECD noticed the relative absence of RTOs, or RTO-like organisations outside the agri-food area. The OECD stated that Ireland could benefit from such organisations as they can act as bridge from HEIs to the private sector and play an important role in supporting SMEs in future innovation activities.

[29] Cf. OECD (2013). *From Bricks to Brains: Increasing the Contribution of Knowledge Based Capital to Growth in Ireland*. OECD Economics Department Working Papers No. 1094.

[30] See also: Higher Education Authority (HEA) (2011). *Sustainability Study: Aligning Participation, Quality and Funding*. Report to the Minister for Education and Skills from the Executive of the HEA November 2011.

In particular they can provide consultancy and technological expertise tailored to business needs and nearer to market activities.

Figure 6 OECD's 2013 recommendations on RTO-like research centres in Ireland

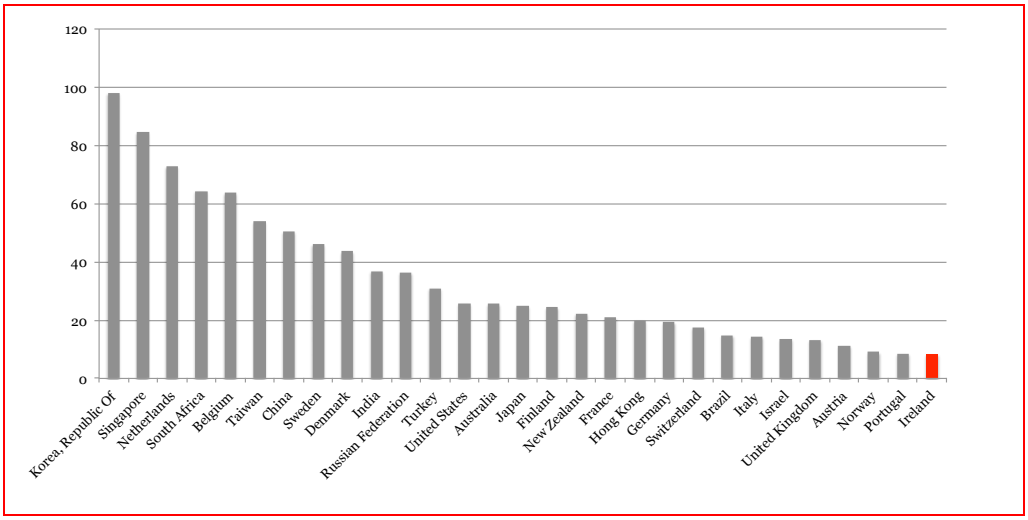
It is important that RTOs are primarily industry-focused and that staff have the incentives to produce industry-focused research. This would mean that their performance and promotion would be based primarily on commercially-related outputs rather than academic ones, such as papers published and citations. To integrate RTOs into the wider innovation system it is important that staff could rotate between them and more academically-focused positions, which would mean treating progression equivalently in an RTO or a more academically orientated centre. (…)

Although the centre landscape is evolving, it does not seem that this gap is being filled in Ireland. The new larger SFI Research Centres (merging CSETS and SRCs) fulfil a different and important role of longer-term strategic research and academic performance metrics remain dominant. Enterprise Ireland's new Technology Centres are industry rather than firm focused and their scale is relatively small and project based and therefore not likely to build the critical mass and continuity that an RTO can bring. The government should move to setting up a pilot RTO.

Source: OECD (2013). *From Bricks to Brains: Increasing the Contribution of Knowledge Based Capital to Growth in Irelan*d. OECD Economics Department Working Papers No. 1094

That same year, Times Higher Education's World Academic Summit Innovation Index showed that academics at leading Irish universities are outperformed by their colleagues in a number of other countries at attracting funding from business. The main conclusions of the Times Higher Education's World Academic Summit Innovation Index are presented in Figure 7.

Figure 7 Average industry contribution per researcher in Ireland vis-à-vis 29 other countries (2012 figures, in 1,000US$ per researcher)



Source: THE (2013). *Times Higher Education's World Academic Summit Innovation Index*

According to the Times Higher Education's World Academic Summit Innovation Index, Irish academics find it difficult to get industry contributions for their research. The market-oriented research centres in Ireland are the main instruments for researchers to attract industry contributions.

2.3 Recent developments in the Irish Research Centre Landscape

The Irish market-focused centre landscape has gone through significant changes since 2012. The main impetus for these changes was the 2012 ACSTI report that concluded that 'a gap exists in the current State-supported research centre landscape that needs to be addressed in order to fully support the commercial opportunities emanating from research'.[31]

2.3.1 Post-2012 developments within SFI that affect the Irish Research Centre Landscape

The 2012 ACSTI Review of the Sustainability of Research Centres highlighted in 2012 that both SFI's CSETs and SFI's SRCs were so-called Group 2 (academic-industry) centres that were established to conduct long-term use-oriented research in academic-industry collaborations to accelerate the exploitation of research outputs in support of medium to long-term industrial and national competitiveness. Even though the CSETs and the SRCs had a 50-50 metrics balance between academic and commercial incentives, they did not directly contribute to the gap that was identified by ACSTI in their 2012 review. In other words, ACSTI believed there was a need of organisations that had *'a greater potential to support the delivery of nearer term impacts to the economy than the more strategic longer term research carried out in many of the Group 2 centres'.*

In parallel with the ACSTI report *Sustainability of Research Centres*, SFI drafted its *Agenda 2020*.[32] In its mission statement, SFI is very clear about its potential contribution to 'the filling of the gap' that was identified by ACSTI: '*SFI will build and strengthen scientific and engineering research and its infrastructure in the areas of greatest strategic value to Ireland's long-term competitiveness and development*'. Therefore, SFI aimed to develop '*a set of research centres that are recognised internationally, that attract international research talent and capital, and that attract, anchor and spin out related companies in Ireland*'. SFI especially wanted to facilitate companies that wish to sponsor or collaborate or partner in research. The target in 2012 was to have 15 of these centres by 2016. At their inception, each SFI Research Centre was to have a minimum of 30 per cent of the total budget committed by industry of which a minimum of 10 per cent is cash.

In its 2013 review,[33] SFI noted that it had launched 7 SFI Research Centres.[34] And more recently in 2014, a further 5 SFI Research Centres were funded.[35] They commenced operations in January 2015. SFI invested €200m in the first set of SFI Research Centres. SFI stressed that its goal is to have a ⅓:⅓:⅓ funding for each of the Research Centres, which would imply that (1) core funding, (2) competitive funding such as awards secured through Horizon 2020, and (3) industry contributions, would be of equal size. SFI's intention is that industry will eventually account for 30 per cent of the total award size in cash through the joint funding of collaborative research projects. In the Irish context, the SFI Research Centres are relatively large (cf. Chapter 4).

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[31] Advisory Council for Science, Technology, and Innovation (2012). *Sustainability of Research Centres*. Forfás, see also: Section 2.1.

[32] Science Foundation Ireland (2012). *Agenda 2020: Excellence and Impact*.

[33] Science Foundation Ireland (2013). *Agenda 2020: 2013 Review*.

[34] APC; IPIC, INSIGHT, MaREI, AMBER, INFANT, and SSPC.

[35] APAPT, iCRAG, LERO, CONNECT and CURAM.

In addition to that SFI launched the new SFI Spokes Programme that would allow Research Centres to grow and evolve by the addition of new industrial and academic partners in November 2013. The Spokes Programme is run as both a fixed and rolling call that requires 10 and 50 per cent respectively in-cash from industry in support of the costs associated with the proposed project.

The differences between the CSETs and the SFI Research Centres are clear: SFI Research Centres have a greater focus in terms of domains (CSETs focused broadly on ICT, Energy, and Biotechnology), the funding horizon is one year longer than was the case for the CSETs, and the SFI Research Centres can scale through initiatives such as the Spokes Programme.[36]. There are some similarities with CSETs, for example, both are joint academic-industry research centres located within universities aimed at conducting high quality mid and longer-term industrially oriented basic and applied research in academic-industry collaborations oriented to applications and industry needs. Additionally, a cohort of the Research Centres previously held CSET awards, so similar research themes prevail.[37] However, the hub and spoke model of the Research Centres is the clear differentiator, in addition to the cost share structure. While the core research focus of the centre is largely academically led, the targeted projects are informed by, and collaborative with, industry. Furthermore, each centre is overseen by an Industry Advisory Board.

During the review process, IDA Ireland and Enterprise Ireland were given an opportunity to review the relevance of the research centre to the current industry base in Ireland. Additional feedback comes from experts from industrial, venture capital and academic backgrounds. By the close of 2014, the SFI Research Centres had 160 signed contracts with industry including 73 MNCs and 87 SMEs.

2.3.2 Post-2012 developments within EI/IDA that affect the Irish Research Centre Landscape

The 2012 ACSTI Review of the Sustainability of Research Centres highlighted in 2012 that the EI/IDA Technology Centres fill a gap in the Irish research landscape. Aside from the NDRC, and NIBRT, they were the only '*Industry Focused*' centres in Ireland in 2012, according to the ACSTI.[38] However, when comparing with overseas industry-focused centres, the ACSTI found that the EI/IDA Technology Centres were both very small in size, and were usually still relatively dependent on the host HEIs. In other words, ACSTI believed there was a need for organisations that had *'a greater potential to support the delivery of nearer term impacts to the economy (…) the current activities of the Technology Centres (TCs) in Ireland'*.

In 2012 both IDA Ireland and Enterprise Ireland were aware of the gap that was identified by ACSTI. Both organisations responded in several ways. In 2013 the ARE Centres that were introduced in Section 2.1 were replaced by the Technology Gateways. Technology Gateways continue to be hosted in IoTs, with the revised programme model emphasising access to technology in IoTs for companies. In addition, the EI/IDA Technology Centres changed over three dimensions: (1) they became subject to slightly different metrics; (2) they were required in their new business plans to target balanced proportions of State, competitive & company funding for Centres (⅓:⅓:⅓ ratio); (3) they were required in their new business plans to adopt operational models appropriate to the needs of companies, and to develop a strategy to drive SME engagement. Our interviewees indicated that even though metrics and incentives are more industry-oriented, many of the Technology Centres still find it hard to reach a critical mass.

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[36] Cf. SFI (2013). SFI Research Centres Programme 2013: Call for Submission of Proposals.

[37] e.g. APC was set up as a CSET in 2003; LERO was set up as a CSET in 2005.

[38] Frontline Consultants (2014). *Technology Centres Programme Interim Evaluation Report*. Final Report to Enterprise Ireland.

Although they do mobilise industry for research, and successfully bring industry partners together, their biggest challenge is to keep industry interested in the long term, and to realise and maintain a constant flow of industrial revenue from a limited set of potential industrial customers. IDA Ireland regrets the fact that the EI/IDA Technology Centres cannot be easily marketed to foreign investors or foreign RDI managers, as they do not have research infrastructures or buildings, and are relatively modest in overall budget in comparison with international centres with which executives in foreign companies would be well familiar

More specifically, through the merger of the Technology Centre in Manufacturing Productivity (ICMR) and the Technology Centre in Energy Efficiency (I2E2), Enterprise Ireland and IDA Ireland are currently creating a particular industry-focused research centre that is (1) larger than other Technology Centres, (2) not allocated to an HEI, and (3) focused on closer-to-market RDI (TRL 4-8) than the current Technology Centres. This new *Irish Centre for Manufacturing Research, Research Organisation* is currently being developed. It receives core funding from the Irish government; it is an independent company, but it still does not have its own infrastructure.

IDA Ireland and Enterprise Ireland have also taken other initiatives to fill the gap identified by the ACSTI in 2012. In the second half of that year IDA Ireland, in association with Enterprise Ireland, conducted an assessment of industry interest in establishing a research centre to support discrete manufacturing, with particular focus on high value products where advanced manufacturing can increase productivity while aspiring to zero defects (e.g. medical devices, microelectronics). IDA Ireland finds that Ireland has significant industry strengths in areas such as medical devices that utilise discrete manufacturing technologies in order to develop and deliver products.

The assessment concluded that there is a positive endorsement of the discrete manufacturing centre concept across all sectors analysed representing 94 per cent of the IDA client's surveyed, and 97 per cent of the EI clients. Moreover, it concluded that such a centre in discrete manufacturing should have a physical presence, with technology and equipment, outside of a traditional HEI setting. The centre would focus on the higher TRL levels and aim to catalyse business-to-business collaboration between MNCs and SMEs (in particular manufacturers and equipment sub suppliers). Even though research might be conducted, it would primarily be a demonstrator centre. This initiative is still in the agenda setting and policy development phase.

The development of the National Institute for Bioprocessing Research and Training (NIBRT) is an important recent development that affects the Irish research centre landscape. NIBRT was set up as a centre of excellence for training and research in bioprocessing. It is a collaboration between University College Dublin, Trinity College Dublin, Dublin City University and the Institute of Technology, Sligo, and was primarily funded by IDA Ireland. IDA Ireland has worked closely with NIBRT after its facility opened in 2011 to ensure that NIBRT was strongly engaged with industry and striving for a ⅓:⅓:⅓ ratio, which it has now achieved. NIBRT's board is composed of a balance of academic representatives, independent agency representatives and several senior executives with corporate responsibility. NIBRT has operated for the last 4 years with a decreasing core budget for RDI partly because. NIBRT did not have direct access to HEA block grant funding and did not receive financial support from member Universities to assist in hiring new PIs. This has made it difficult for NIBRT to compete for competitive funding. IDA Ireland states that this is now changing with the new core RDI funding stream of €1.5m per year and potential leverage from several universities. IDA board has recently approved an addition €7.5m in core research funding over 5 years to further grow NIBRT's research budget while still maintaining the ⅓:⅓:⅓ ratio. NIBRT is now actively working with Enterprise Ireland to engage with indigenous companies.

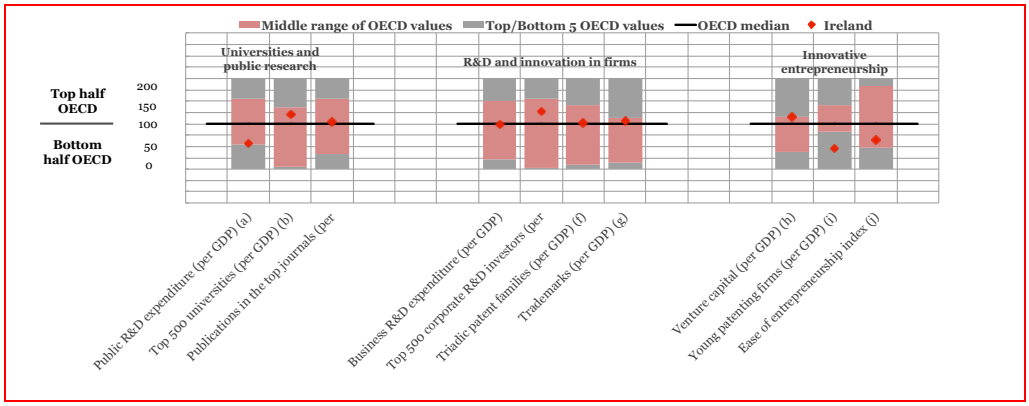
2.4 The Irish enterprise base at the beginning of 2015

The 2014 Action Plan for Jobs concludes that 'Ireland is emerging from a deep and prolonged recession and signs of economic recovery are increasingly evident'. The Action Plan also concludes that Ireland's international competitiveness has improved significantly in recent years, and it notes that net exports have been driving economic activity in Ireland since 2008. Even though the Action Plan is positive about what has been achieved by Irish enterprises in the last few years, it identifies cost competitiveness as a critical issue for Ireland. Costs of labour are relatively high, and growth in productivity performance is mainly realised by a small number of high productivity exporting sectors. The Action Plan also mentions the EU's Innovation Scoreboard, which identified Ireland as an 'innovation follower', suggesting that it does not per se reflect the strength of its universities. Manufacturing remains a relatively important part of the Irish economy in comparison to other European countries.

In its 2014 Science, Technology and Industry Outlook 2014, the OECD assesses the state of the Irish enterprise and STI base at the beginning of 2015.[39] The OECD notes that Ireland has relatively many top corporate RDI investors which is due to the strong presence of knowledge intensive MNCs. The bulk of Ireland's BERD is performed by foreign affiliates, partly owing to the well-educated workforce, the financial regime and the outputs of IDA Ireland. The majority of IDA Ireland supported RDI projects in the MNC base are in areas of process and late-stage product development supporting manufacturing in bio-pharma, medical devices and ICT.

Public RDI expenditures (per GDP) are 43 per cent below the OECD median, and slightly above the bottom 5 OECD countries. Business RDI expenditures are at the OECD median level. Since corporate R&D investors in Ireland spend 21 per cent more on RDI than in other countries, one can conclude that at the beginning of 2015, SMEs in Ireland spend relatively considerably less on RDI than SMEs in other countries. The presence of young firms among patent applicants underlines the inventive dynamics of firms early in their development. It was already noted that two-thirds of all new jobs in Ireland come from start-ups in the first five years of their existence. However, the share in Ireland of patents filed by young patenting firms is 56 per cent below OECD average, which places Ireland in the bottom 5 OECD countries.[40]

Figure 8. Relative performance of Ireland's science and innovation system



Source: OECD (2014). OECD Science, Technology and Industry Outlook 2014

[39] OECD (2014). *OECD Science, Technology and Industry Outlook 2014*. Paris.

[40] OECD (2014). *OECD Science, Technology and Industry Outlook 2014*. Paris.

3. Growth and ambitions for 2025

The previous chapter showed that the Irish STI system is still relatively young. One should be aware of the fact that Ireland embarked on a strategy from the late 1990s onwards of significantly enhancing the scientific, technological and innovative capacity of the enterprise sector and the country as a whole.[41]

The Chapter at hand focuses on Irish ambitions for the upcoming years. The findings in this chapter are based on desk research, on interviews with high-level representatives of the Department, the relevant agencies, the HEIs, and industry, as well as on inputs of an Expert Workshop and two Stakeholder Workshops.

Despite the young age of substantial investments in the system, the ambitions for the next decade in terms of market-focused research are clear. Ireland needs appropriate translational capacity to bridge research and technology commercialisation and needs to provide Irish enterprise with access to capability and infrastructure to support research and innovation activities now and into the future.[42] This implies that in the next decade, it is inevitable to further increase the competitiveness of its market-focused research centre landscape. The figure below presents the ambitions of some of the various stakeholders in this respect.

Figure 9 Longer term ambitions of various stakeholders for the upcoming years

Stakeholder	Organisation
Department of the Taoiseach	'The current strategy is focused on accelerating the economic and societal return on our STI investment, further strengthening enterprise engagement with public research and driving more commercialisation of publicly performed research.'[43]
IDA Ireland	"While IDA has seen strong growth in R&D based investment in our client base in recent years, the majority of our clients are investing in experimental development (late stage applied research in the area of TRL 5-9). One of the most R&D intensive sectors is life sciences, where companies in the areas of biopharmaceuticals and medical devices are developing new and improved manufacturing processes to produce the latest drugs and devices to the highest quality standards. Almost none of IDA's client companies in this sector are involved in early stage fundamental research (TRL 1-5) in these areas."[44]
NRPSG	'A key objective is to accelerate the delivery of economic outcomes from Government investment in public research organisations by implementing the recommendations contained in this Report on Research Prioritisation'.[45]
DJEI	'In encouraging industry and RPOs to work together, the State's aims are (…) for Ireland's academic centres of excellence to be the global partners of choice in Collaborative Research Programmes which industry will engage in.'[46]
SFI	A key objective of SFI's Agenda 2020 is to develop a set of world-leading, large-scale research centres that will provide major economic impact for Ireland. The goal of SFI, in partnership with its sister agencies and departments, is to develop a dynamic research centre ecosystem that can evolve to meet the changing needs of industry and society. Additionally, the SFI Spokes Programme will provide an on-going mechanism for new partners to join existing Research Centres and also to link Research Centres. [47]

41 Forfás (2012). *Report of the Research Prioritisation Steering Group.*

42 Forfás (2014). *Request for tender for consultancy to undertake a study on: Medium Term Development of the Market-Focused Element of the Irish Research Centre Landscape.*

43 Department of the Taoiseach (2014). *Action Plan for Jobs.*

44 IDA Ireland, additional comments, March 2015.

45 Forfás (2012). *Report of the Research Prioritisation Steering Group.*

46 DJEI. *Putting public research to work for Ireland. Policies and procedures to help industry make good use of Ireland's public research institutions.*

47 Science Foundation Ireland (2012). *Agenda 2020: Excellence and Impact.*

Stakeholder	Organisation
Enterprise Ireland	'An (…) important element of our agenda is the work we do with Ireland's universities and institutes of technology to ensure the maximum commercialisation of market-relevant intellectual property and discoveries that they generate.'[48]
HEA	In 2020, 'a strong engagement between higher education and enterprise has the potential to play a vital role in enhancing Ireland's economic competitiveness'. 'Innovation must be the driving force behind such engagement: innovation in teaching, learning and research from higher education; and innovation in taking advantage of learning opportunities from the business community.'[49]

Such a landscape would need to be holistic in the sense that the large proportion of firms in Ireland would find the expertise needed for innovation and growth. Research-performing organisations would therefore serve the needs of companies in various sectors, and cover various technologies. Such a landscape would also need to be holistic in the sense that it would serve demand for various types of research. In 2025, research-performing organisations would operate at all research maturity levels, from basic technology research and concept validation (TRL 1-3) and applied RDI (TRL 4-5), to demonstration projects (TRL 6-7), and pre-commercial deployment (TRL 8-9). This would appear to be particularly important given the feedback from IDA Ireland that the majority of its research active clients are operating at TRL 5-9.

The landscape should support companies operating in earlier TRLs, and SFI Research Centre activities do give the impression that this is currently being done by the SFI Research Centres. Yet a lack of capability in the public research ecosystem at TRL 5-9 may result in poor cross-over between public and private RDI activity at these TRL levels. This implies that in 2025 the Irish market-focused research centre landscape captures the assets of the Irish HEIs that have a footprint in basic research, but it would also have very strong and cross-sector capacity when it comes to technological, consultancy, and other knowledge-related solutions with a shorter-term focus. This implies that in the 2025 landscape there need to be different types of research performing organisations that provide different types of research and development services to a wide range of Irish-owned firms and to foreign-owned firms.[50] Yet it also needs to be clear that Ireland cannot be strong in all research priority areas, domains and sectors. Thus a key challenge is to identify those domains and value chains where Ireland has the potential to become world class.

The road to 2025 is relatively clear. Technical innovation in Ireland, according to the OECD, is low by EU15 standards and would need to increase in the next decade. Industry in Ireland needs to become more knowledge-driven, and would need to reap greater rewards from a wider range of innovation activities. Efforts to foster innovation in Irish-owned SMEs as well as multinationals should continue, according to the OECD, while further building linkages between the foreign and Irish-owned industry and the Irish market-focused research centre landscape. Only then, can Irish industry move away from 'bricks and mortar', according to the OECD, towards accumulating knowledge-based capital.

[48] Enterprise Ireland (2014). *Annual Report 2013.*

[49] HEA (2010). *National Strategy for Higher Education to 2030*. Report of the Strategy Group.

[50] Cf. OECD (2013). *From Bricks to Brains: Increasing the Contribution of Knowledge Based Capital to Growth in Ireland*. OECD Economics Department Working Papers No. 1094.

The data presented in this report provide a good overview of Ireland's research centre market-focused functions for the supply side of research. The data provide several logical arguments for increased investments in higher TRL, and closer-to-market, research activities. In addition to these data, it should be pointed out that there are also four key logical arguments that could be used to argue for considering a transition towards a more market focused Irish research centre system:

- Ireland requires to increase the competitiveness of its SMEs, and more market-focused research centre capacity is needed for that.
- The Irish research centre system should, in any case, be flexible enough to accommodate *potential future demand* for more applied research services, regardless of the exact current demand profile at the moment.
- Ireland should be aware of international best practice investment profile and institutional arrangements for remaining competitive and building Ireland's reputation as a location of choice for investment. Figures presented in Section 2.4 do not fully support this profile.
- Rational policy planning and implementation for a transition toward a more-market focused research centre landscape can take many years to take full effect. Ireland should anticipate future developments.

This implies challenges for industry in Ireland, as well as for the research centre landscape in Ireland. The next chapter discusses the current research centre landscape and the extent to which the research performing organisations are ready to meet the future needs of industry in Ireland.

4. The current state of Ireland's market-focused research capacity

The previous chapter set out Ireland's research and enterprise policy ambitions and consequent implications for the research centre landscape. The progress made in the last few years cannot be missed. For example, since 2005 the average number of licences, option or assignment agreements executed each year by HEIs with companies was up sevenfold to 85, and the number of spin-out companies created each year was averaging 22, an increase of nearly 450 per cent. Another example of progress concerns the SFI Research Centres that (as of the end of 2014), have 160 signed contracts with industry, while SFI recently awarded two tranches of funding through their Spokes programme, designed to enable SFI Research Centres to grow and evolve.

However, the chapter also showed that Ireland must ensure that in 2025 it has appropriate translational capacity to bridge research and technology commercialisation and provide Irish enterprise with access to capability and infrastructure to support research and innovation activities. Publicly-funded market-oriented research centres should be able to provide the research, development and innovation products and services that are closely aligned to companies' needs. Such a demand-driven system (combined with a presence of excellent basic research) will help Ireland-based firms in improving global competitiveness in their respective markets.

The chapter at hand assesses the market-focused element of the Irish research centre landscape, taking into account recent developments in order to identify gaps and opportunities to build on the existing landscape to ensure an internationally competitive market-focused research centre landscape in Ireland. The findings in this chapter are based on Eurostat, and OECD data. In addition, surveys constructed together with EI and SFI, and sent by EI and by SFI to all EI/IDA Technology Centre directors and all SFI Research Centre directors, and that questioned them on activities performed in their centres, prognoses, and client bases. The response rate was 95% of all centre directors addressed. DJEI sent out surveys to Tyndall, NIBRT, and to Teagasc, who all responded. The assessment consists of the six components illustrated in Figure 10. Each component is discussed in a separate section. Figure 10 also presents the main findings per component.

Please be aware that in-depth data from overseas comparators are detailed in the next chapter. The chapter at hand will regularly refer to findings in Chapter 6 to draw comparisons between the market-focused research centre landscape in Ireland and those in other countries.

Figure 10 Components of the assessment of the market-focused research centre landscape in Ireland and the main findings per component

Component	§	Main findings
Investments in the Irish system. Expenditures on basic research, applied research, and on experimental development in Ireland compared with several other countries.	4.1	1. Total R&D expenditures (GERD) in basic research, applied research, and to a lesser extent experimental development are slightly lower than in most comparator countries. Especially basic and applied research expenditures are relatively low in Ireland 2. The public share of these investments is small compared to most EU countries and can be compared to the shares in e.g. Latvia or Italy. Much of the research seems to be funded by industry and seems to be performed either in-house or overseas.
Industry participation in the Irish centres. Size and industry contributions of Irish centres compared to some overseas comparators	4.2	3. The Irish state-funded research centres have a lower share of private funding (both in cash or kind) compared with organisation serving similar research functions in several countries of comparable size, including e.g. Denmark, The

Component	§	Main findings
		Netherlands, Austria, and Belgium.
Closeness to market uptake of research conducted in the Irish research centres (now). The current state-funded portfolios of the Irish centres in terms Technology Readiness Levels (TRLs).	4.3	4. The aggregated public investment in RDI through the EI/IDA and SFI centres are highest on the lower technology readiness levels. The EI/IDA Technology Centres themselves operate relatively close to market, but their size is small. SFI research centres currently focus on TRL 1 to TRL 3. 5. Sector-specific centres (Tyndall, NIBRT, and Teagasc) operate across a broad TRL spectrum and therefore also closer to market entrance, yet it must be clear that their direct added value for Ireland is limited to their specific client base.
2016 prognoses on closeness to market uptake of research conducted in the Irish research centres. Centre directors' expectations on 2016 TRL distributions.	4.4	6. At the consolidated level, the EI and the SFI centres expect an increase of activities on TRL 3; TRL 4 and TRL 5. This growth is mainly attributable to prognoses of SFI research centre directors (42% increase in weighted average in terms of TRLs), and to a lesser extent attributable to prognoses of EI/IDA Technology Centre directors (2% increase in weighted average in terms of TRLs). 7. Beyond TRL 5 the EI/IDA and SFI centre directors expect no increase in activities. Companies that need research and development that is more mature than TRL 5 depend on the small EI Technology Centres capacity, and on sector oriented research capacities in Teagasc, Tyndall, and NIBRT. 8. The sector-oriented centres (Teagasc, Tyndall, NIBRT) predict incremental developments in their activities at the higher TRL levels.
Specific research functions provided. The research activities that the centres undertake.	4.5	9. Research centres in Ireland (both the EI/IDA and SFI centres, as well as the sector-oriented centres) invest a large share of their resources in medium term problem-oriented research (including collaborative research). In addition, the SFI centres also invest substantially in oriented basic research.[51] 10. EI and SFI centres as a group spend only small portions of their resources on typical near-market-focused research and services such as consultancy, contract research services, and short-term applied research.

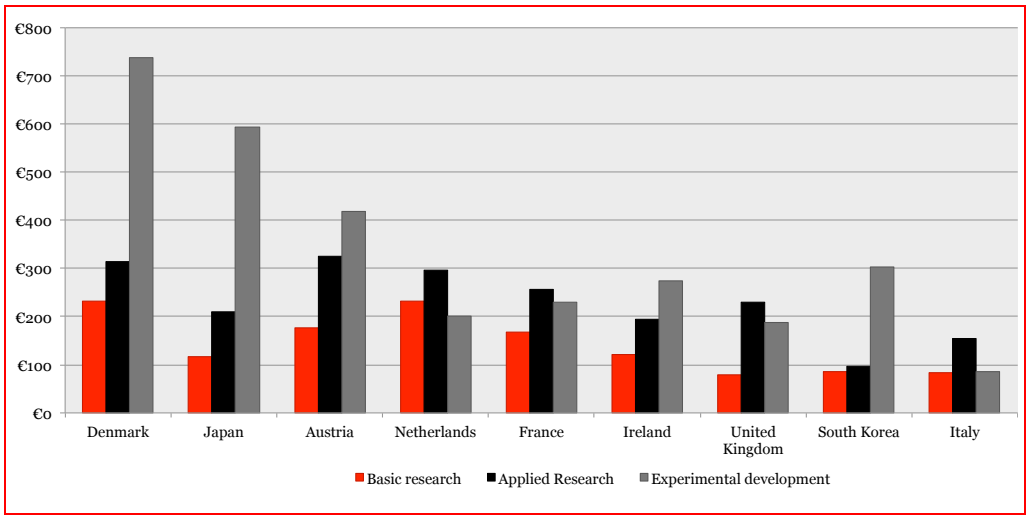
Source: Technopolis Group

[51] Definitions are presented in Section 4.5.

4.1 Investments in Ireland: total R&D expenditure (GERD) by type of R&D activity in Ireland compared with several other countries

Combined RDI expenditure (GERD) expenditures on basic and applied research, are relatively low in Ireland. This was noted by several stakeholders, ranging from the IUA[52] to the OECD.[53] Figure 11 presents the total private and public investments in research capacity in three different levels of research/technology maturity.[54] Irish (combined public and private) investments in basic research, and applied research are relatively low compared with those of similar countries. Ireland's (combined public and private) expenditures per inhabitant on experimental development can be compared to those of countries such as The Netherlands, and the UK.

Figure 11 Total of public and private RDI expenditures (GERD) per inhabitant by type of RDI activity for several countries (2008-2012 averages)



Source: Eurostat. Sample based on data availability to allow for 2008-2012 average calculations. Only very few countries publish these statistics.

At first sight the figure above seems to give a positive impression of the market-focused research centre capacity in Ireland. However, two important remarks should be made.

In the first place, one should be aware that experimental development does not include several of the typical RTO-like functions, such as testing, and consultancy services (Cf. Section 1.1.2 and Figure 6).

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[52] Patrick Prendergast (2014). *The Role and Contribution of Universities*. Key note at the IUA Symposium: 21st Century Universities – Performance and Sustainability.

[53] Cf. OECD (2013). *From Bricks to Brains: Increasing the Contribution of Knowledge Based Capital to Growth in Ireland*. OECD Economics Department Working Papers No. 1094.

[54] Data in Figure 11 follow OECD/Frascati Manual definitions. Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. Applied research is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed to producing new materials, products or devices; to installing new processes, systems and services; or to improving substantially those already produced or installed.

In the second place, it should be noted that in Ireland applied research, as well as experimental development, is largely being funded by the private sector, where it almost exclusively takes place. Especially experimental development is largely non-existent in the HEI and private non-profit (independent research centres) sectors. This is a clear conclusion from our interviews, but it is also made clear by the EU Innovation Scoreboard that locates – in its underlying data – Ireland between Latvia and Italy when it comes to public expenditures on innovation. Ireland's public expenditures relative to GDP are 29 per cent below EU average.[55]

The situation in Ireland is quite different from other countries with a relative focus on experimental development, such as Denmark.[56] In these countries, the government has a more prominent role in encouraging applied research and experimental development. This would suggest that while there is a substantial amount of experimental development taking place in business in Ireland, the integration of these expenditures with the publicly-funded research centre system (HEI + non-profit private) is still relatively weak.[57] This indicates that Irish business pursues experimental development almost fully in-house or outside Ireland, which could suggest a market potential for more close-to-market research centres in Ireland. This issue will be further explored in Section 5.

4.2 Industry participation in the Irish centres: size and industry contributions of Irish centres compared with some overseas comparators

The Irish state-funded research centres have an explicit market-focused mission. In Ireland they are the largest body of non-sector-specific and non-technology specific state-funded research capacity with a clear market orientation. The size of individual centres is however small compared with market-focused research centres in other countries. This is clearly shown by Figure 12, which compares the consolidated resources of the EI/IDA Technology Centres and the SFI Research Centres with those of a small sample of overseas market-focused research centres (individual research centres). This issue was also addressed by, for example, the ACSTI in 2012, by the OECD in 2013, and in the interim evaluation of the EI/IDA Technology Centres in 2014.

Yet, Figure 12 also presents valuable information on the roles of industry in the centres in Ireland as both public core funding, and private co-funding (cash & in-kind) are included in the figure.[58] Apart from the relatively small size of individual centres,[59] their private co-funding shares are also relatively small. Both SFI Research Centres, and EI/IDA Technology Centres are young, and work hard to increase private contributions, but compared with overseas centres, the Irish centres depend relatively much on the public core funding.

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[55] EUROSTAT, IUS 2014 Database, Annex A; and Section 1.3.1

[56] OECD R&D Statistics.

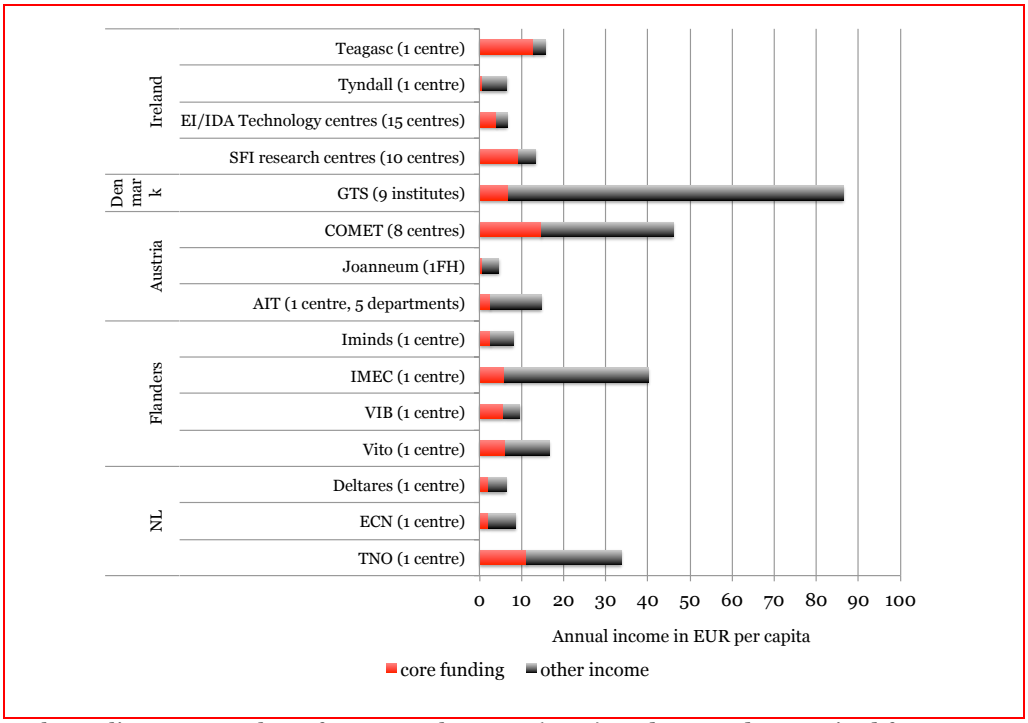
[57] Note that the last available data are from 2011, so there may have been evolutions since that date.

[58] Core funding is defined as either programme funding directed specifically at supporting research centres or recurrent grant-in-aid funding. The former is typically fixed-term with the possibility of more than one fixed term funding cycles e.g. funding from the EI/IDA Technology Centres and the SFI Research Centres. For the latter, funding is indefinite and dependent on the policy objectives of the funding Government Department or agency (cf. ACSTI, 2012). Competitive funding (e.g. Horizon 2020 grants) is not included in the data for any of the organisations, as no harmonised metrics were available (see also Figure 4).

[59] See also Figure 12.

The characteristics of the ACSTI Group 2 (Academic-Industry Centres) centres include that private funding covers 30-40 per cent of total resources, while the ACSTI Group 3 (RTO) receive 50-70 per cent of their budgets from industry.[60] The EI/IDA Technology Centres and the SFI Research Centres seem closer to the first distribution than to the second.

Figure 12 Annual budgets of Irish research centres per capita compared with selected overseas centres (public core funding and private funding, no competitive funding)



Technopolis Group, analyses from annual reports (2013), and survey data received from EI, SFI, Teagasc, and Tyndall. Core funding is defined as 'either programme funding directed specifically at supporting a research centre or recurrent grant-in-aid funding for a research centre' (see also Figure 4)

4.3 Closeness-to-market uptake of research conducted in the Irish research centres: the current state-funded portfolios of the Irish centres in terms of Technology Readiness Levels (TRLs)

Figure 14 presents the current annualised portfolio of the Irish state-funded centres' research capacity in terms of Technology Readiness Levels (TRLs). This TRL scale serves as a clear indication of the closeness to market of the research conducted in Ireland.

[60] E.g. Technopolis Group (2012). *Research Centres in Ireland: Funding Models, Oversight Mechanisms and Vision of a Future Research Centre Landscape*. An independent report to Forfás by Technopolis Ltd; and: Kristiansen, Ernst (2012). *Large RTOS in the FP7 Cooperation Programme*. EARTO, SINTEF.

Figure 13 Explanation of the Technology Readiness Levels (TRLs) scale

The Technology Readiness Level (TRL) is a measure of the maturity of a technology. Its purpose is to assist technology managers and investors in making decisions concerning the development and transitioning of a technology. As a technology is developed from the initial phase (basic principles observed, TRL 1), it progresses through a number of TRLs (the TRL scale) until it is finally deployed in an operational setting (TRL 7).

From its genesis in project management and systems integration, the TRL scale was intended to assist technology managers in identifying those elements and processes of technology development required to ensure that a project satisfies its intended purpose in a safe and cost-effective manner that will reduce life cycle costs and produce results that are defensible to expert reviewers.

As Technology Readiness Levels (TRLs) are used to define the different research and innovation steps going from basic research to the commercialisation of a product, they offer a clear indication of maturity of research conducted. In Horizon 2020, distinction is made between the following levels of maturity:

1. *basic principles observed*
2. *technology concept formulated*
3. *experimental proof of concept*
4. *technology validated in lab*
5. *technology validated in relevant environment*
6. *technology demonstrated in relevant (industrially relevant) environment*
7. *system prototype demonstration in operational environment*
8. *system complete and qualified*
9. *actual system proven in operational environment (competitive manufacturing)*

As a tool for assessing market orientation of the research centres, the TRL analysis of the current portfolios of has clear pros and clear cons. The cons were clearly described by EARTO in 2014[61] and include the need for more attention to setbacks in technology maturity. We are aware that the analysis offers a picture that does not respect the strong dynamics in the centres in general and in certain projects in particular. We are also aware that even though activities in the higher TRLs correlate with a strong industry involvement, activities in TRL 1, and TRL 2 do not automatically imply that industry is not involved

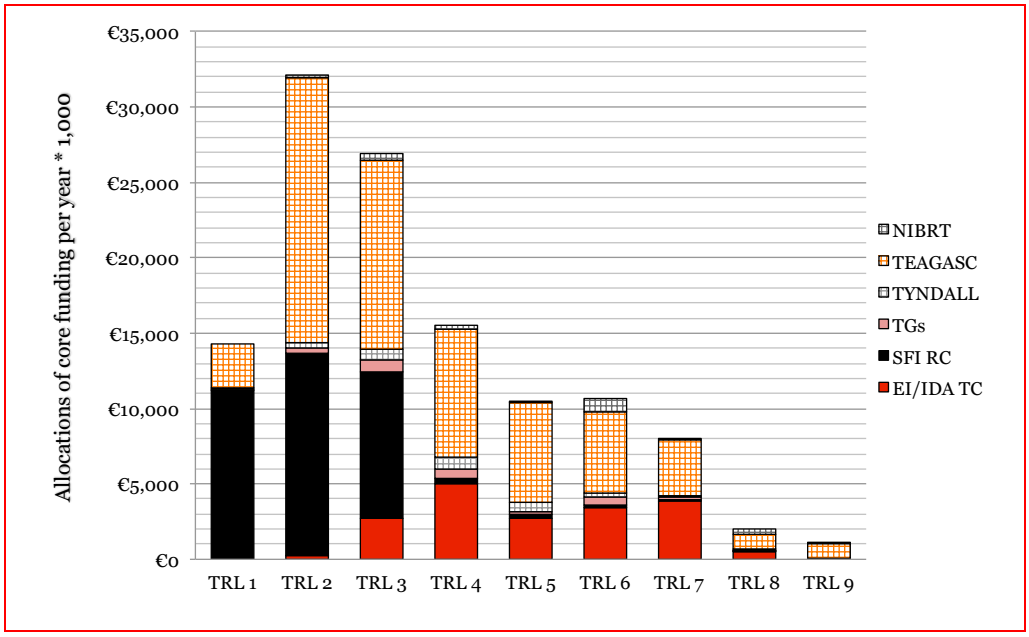
The benefits of the scales are also clear. The categories are widely used and understood. They give a structured and common understanding of the maturity of the research that is being conducted: the higher the TRL value, the closer a product or a service is to the market. In Horizon 2020 these categorisations are intensively used by the European Commission.

RTOs are generally active throughout the entire TRL scale. From TRL 4 to TRL 7, this is believed to be the most prominent RTOs area, according to EARTO.

These data are based on surveys that were validated by EI and SFI. The directors of the SFI Research Centres, the EI Technology Centres, NIBRT, Teagasc, and Tyndall filled out the surveys and sent them to Technopolis Group via DJEI or the funding organisations. We are aware that different industries, dependent on their sector, will use the TRLs differently, and this will make lining them up with each other challenging. We mitigated this risk by using generally accepted definitions to which EI and SFI agreed, and clearly communication them to the centre directors in a way that was discussed with EI and SFI before launching the survey. Data cover core funding.

[61] EARTO (2014). *The TRL Scale as a Research & Innovation Policy Tool, EARTO Recommendations.*

Figure 14 2014 core funding portfolios of the Irish state-funded centres in terms of TRLs



Source: Technopolis Group.[62] Core funding is defined as 'either programme funding directed specifically at supporting a research centre or recurrent grant-in-aid funding for a research centre' (see also Figure 4)

Figure 14 shows that the consolidated Irish state-funded centres operate predominantly at low technology readiness levels. The SFI Research Centres are active in TRL 1 to TRL 3. The EI Technology Centres operate in TRL 3 to TRL 7, but their volume is relatively limited in absolute terms. Tyndall, NIBRT, and Teagasc operate in the field from TRL 2 to TRL 6 or even TRL 7, but their direct value added is very much limited to a small part of Irish businesses.

All levels beyond TRL 3 receive both in relative terms and in absolute terms relatively few resources, especially compared with TRL 2 and TRL 3. The resources that are available to these higher TRL levels are only accessible to companies in specific sectors. Companies outside the Tyndall, NIBRT, and Teagasc client base depend on the scarce resources in the EI Technology Centres. In other words, outside the domains of Tyndall, NIBRT, and Teagasc, there is little state-funded activity in the centres beyond TRL 3. The bulk of the research that is being performed is relatively distant from market.[63]

In Section 6.3 it is made clear that the EI/IDA Technology Centres have distributions that are in line with those in the Fraunhofer Institutes and, for example, IMEC. Moreover, the sector-oriented research centres in Ireland also have distributions that resemble the distributions of typical RTOs like Fraunhofer. Yet, the larger SFI Research Centres can only be compared to the former Swedish Competence Centres in terms of the closeness to market of their RDI.

[62] EI/IDA TC totals based on EI/ IDA reports, distributions based on Technopolis surveys. SFI RC totals based on SFI reports, distributions based on Technopolis surveys. TG totals based on EI reports, distributions based on Technopolis surveys. Tyndall totals based on Annual Accounts (2013), distribution based on Technopolis surveys. Teagasc totals based on DJEI, distribution based on Technopolis surveys. NIBRT totals based on IDA reporting, distribution based on Technopolis surveys. Technopolis surveys asked for total portfolio shares.

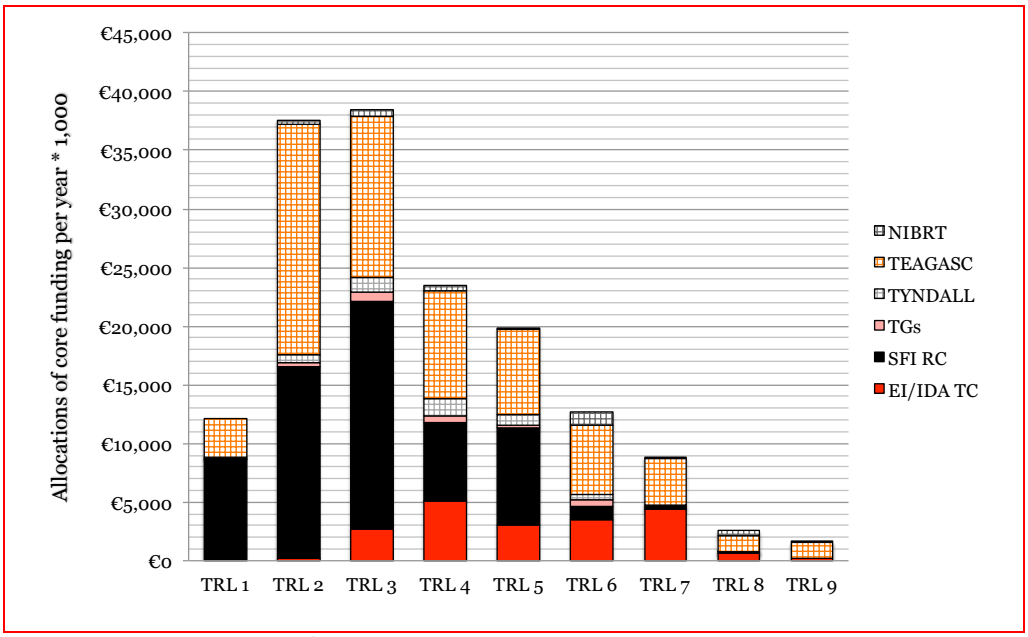
[63] Detailed figures per Priority Area are presented in the Appendix.

We are aware of their young age, but one should also be aware that – in their allocation of resources – research organisations usually do not follow technological developments in their growth in terms of TRLs. In other words, research organisations have a tendency to stick to the TRLs in which they feel comfortable and in which they are good.[64] The 2016 prognoses of the centre directors in Ireland are clear proof of this.

4.4 Closeness to market uptake of research conducted in the Irish research centres (2016): centre directors' expectations on 2016 TRL distributions.

Figure 15 presents the expected 2016 portfolio of the Irish state-funded centres research capacity in terms of Technology Readiness Levels (TRLs). Methodologies are in line with those presented in Section 4.3. Prognoses are based on surveys filled out by all individual centre directors. Given that in 2016 the main transition from CSET and SRC to SFI Research centres will be complete and many centres will be halfway their current remit, this year represents a 'current policy equilibrium'.

Figure 15 Expected 2016 core funding portfolios of the Irish state-funded centres in terms of TRLs



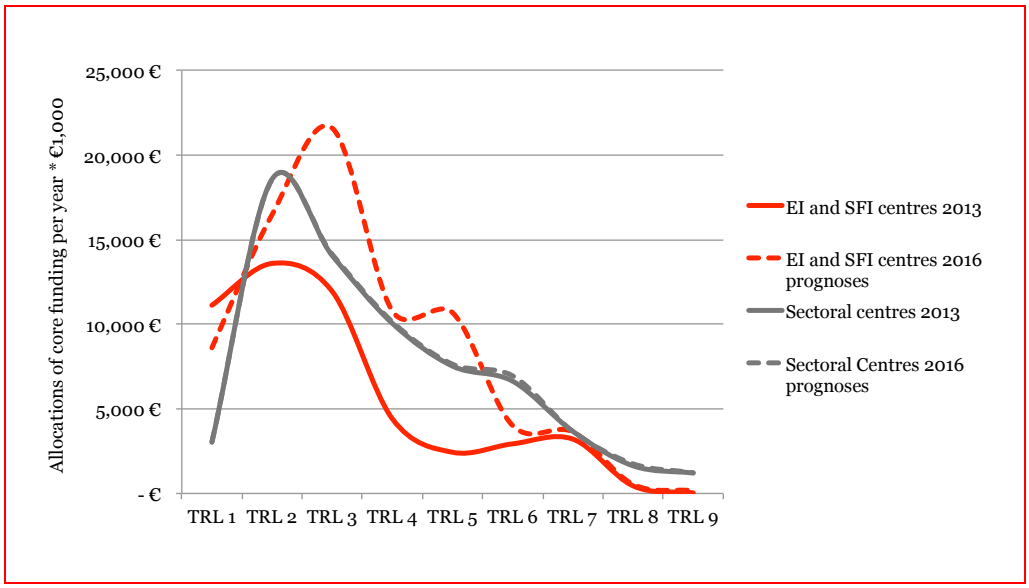
Source: Technopolis Group.[65] Core funding is defined as 'either programme funding directed specifically at supporting a research centre or recurrent grant-in-aid funding for a research centre' (see also Figure 4)

[64] See also e.g. Lamont, M. (2009). *How professors think. Inside the curious world of academic judgment*. Cambridge: Harvard University Press; Auriol, L., Felix, B. & Schaaper, M. (2010). *Mapping careers and mobility of doctorate holders*. STI Working paper 2010/1. Paris: OECD; Van Arensbergen, P. & Van den Besselaar, P. (2012). The selection of scientific talent in the allocation of research grants. *Higher Education Policy*, 25, 381-405.

[65] EI/IDA TC totals based on EI/ IDA reports and Technopolis surveys, distributions based on Technopolis surveys. SFI RC totals based on SFI reports and Technopolis surveys, distributions based on Technopolis surveys. TG totals based on EI reports and Technopolis surveys, distributions based on Technopolis surveys. Tyndall totals based on Annual Accounts (2013) and Technopolis surveys, distribution based on Technopolis surveys. Teagasc totals based on DJEI and Technopolis survey, distribution based on Technopolis surveys. NIBRT totals based on IDA reporting, distribution based on Technopolis surveys.

Figure 15 shows that in 2016, the Irish centre directors expect increased activities in TRL 4 and TRL 5, and reduced activities in TRL 1. The overall volume will also increase. These developments are also reflected in Figure 16. This figure shows in red the EI and SFI centres, while the grey lines reflect the other sector-oriented centres. For both groupings the solid lines show the 2013 situation, while the dotted line shows the 2016 prognoses by the centre directors.

Figure 16 Centre activities in 2013 vis-à-vis 2016 in terms of TRLs (aggregated based on core funding per annum * €1,000; prognoses by the directors of the respective centres)



Predictions of totals: see Figure 14 & Figure 15. Core funding is defined as 'either programme funding directed specifically at supporting a research centre or recurrent grant-in-aid funding for a research centre' (see also Figure 4).

The total volume of the EI and SFI centres increases due to the inflow of new centres. The EI and the SFI centres expect an increase of activities in TRL 3, TRL 4 and TRL 5. This growth is largely caused by the SFI research centre directors who expect a natural development in individual research projects from basic research towards more applied research, and prototyping. This implies a decrease of activities in TRL 1. Beyond TRL 5 the EI and SFI centre directors expect no additional activities. The sector-oriented centres (Teagasc, Tyndall, NIBRT,) do expect minor and incremental developments in their activities in their distributions.

In 2016 the consolidated focus of EI/IDA and the SFI centres will still be on the lower TRL levels. This is where the bulk of their aggregated activities currently take place, and where – according to the centre directors – it will take place in 2016. Companies that need research and development that is more mature than TRL 5 depend on the small EI Technology Centres capacity, and on sector-oriented research capacities in Teagasc, Tyndall, and NIBRT.

This implies that our conclusions from Section 4.3 will still stand in 2016. The EI/IDA Technology Centres will have activities that are in line with those in the Fraunhofer Institutes and, for example, IMEC in terms of TRLs. Moreover, the sector-oriented research centres in Ireland will also have distributions that resemble the distributions of typical RTOs like Fraunhofer.

The larger SFI Research Centres are in transition to somewhat higher TRL levels, but the relative absence of activities above TRL 5 implies that they can only be compared to the Swedish Competence Centres in terms of technology readiness levels.

4.5 Specific research functions: the research activities that the centres undertake

We distinguish four types of research that were identified together with SFI and Enterprise Ireland. These are:

A1. Oriented basic research

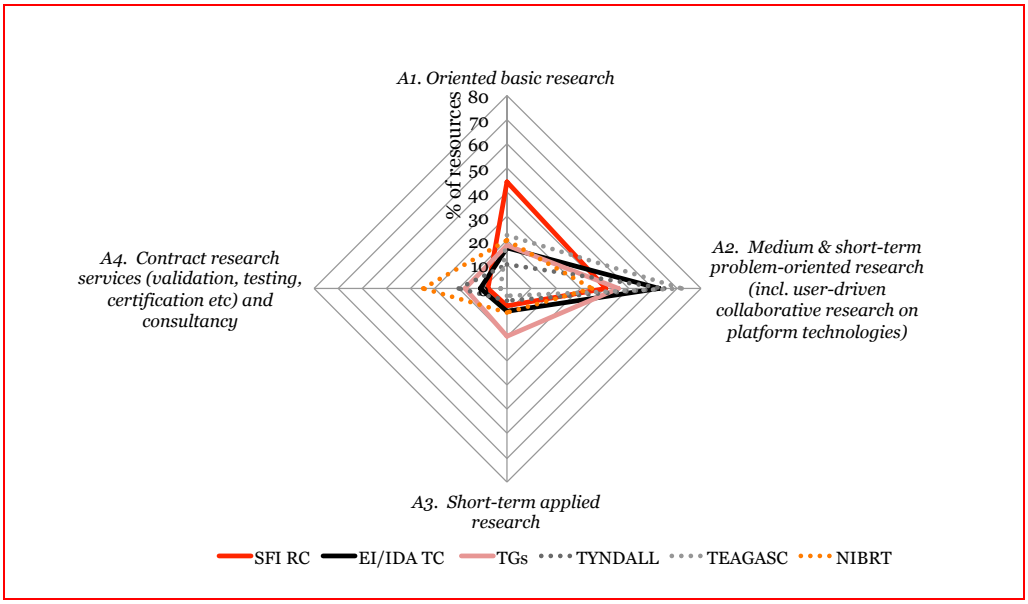
A2. Medium & short-term problem-oriented research (incl. user-driven collaborative research on platform technologies)

A3. Short-term applied research

A4. Contract research services (validation, testing, certification etc.) and consultancy

The categorisation is based on several sources[66] and on feedback from SFI and EI. The figure below presents the relative allocation of resources on these functions for the EI/IDA Technology Centres, and the SFI Research Centres, as well as for Tyndall, Teagasc, and NIBRT. Data are based on the assessments of the directors of all centres whom we asked to assess the actual priorities in their organisations in terms of actual resource allocations. No distinction is made between core funding and additional funding. .

Figure 17 Research functions for industry, self-assessments of priorities per (group of) organisation(s) (reference year: 2014)



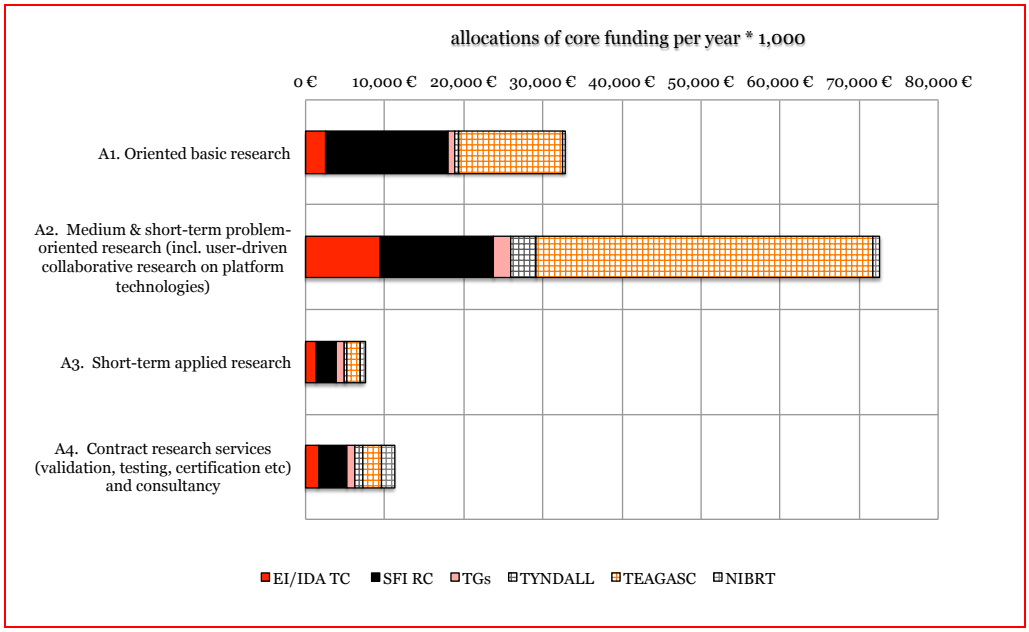
Sources: see Figure 14. We asked all individual centre directors to assess the actual priorities in their organisations in terms of actual resource allocations. No distinction is made between core funding and additional funding.

[66] E.g. Sverker Sörlin, Erik Arnold et al., *A Step Beyond: International Evaluation of the GTS Institutes*, Ministry of Science, Technology and Innovation, Copenhagen, 2009; Erik Arnold, Zsuzsa Jávorka and John Clark, *Impacts of RTOs: A Study of Social and Economic Impacts of Research and Technology Organisations*, Brussels: EARTO, 2010; Erik Arnold et al., *The Role of Industrial Research Institutes in the National Innovation System*, VA 2007:12, Stockholm, VINNOVA, 2007.

The main message from Figure 17 is that the EI and SFI centres as a group spend less than 10 per cent of their resources on typical RTO services such as consultancy and This is not surprising, as the SFI Research Centres and the EI/IDA Technology Centres were set up to perform collaborative research, research services (A4) and short-term applied research (A3; less than 8% of resources).

The centres in Ireland (both the EI/IDA and SFI centres, as well as the sector-oriented centres) invest much of their resources in medium & short-term (collaborative) problem-oriented research (A2). In addition, the SFI centres also invest substantially in oriented basic research. Similar conclusions should be drawn when looking at the figure below that presents annual core funding of the centres on these four functions.

Figure 18 Research functions for industry, distributions of resources per organisation



Sources: see Figure 14. Core funding is defined as 'either programme funding directed specifically at supporting a research centre or recurrent grant-in-aid funding for a research centre' (see also Figure 4)

This implies that the market-focused research capacity in Ireland is largely focused on medium and short-term problem-oriented research. There is no doubt that this type of research is of great value for Irish companies, given the fact that a substantial number of firms are participating and contributing to these centres. However, other typical RTO and market-focused RDI services such as consultancy, contract research (e.g. for testing and certification), and short-term applied contract research (including demonstration) receive relatively less attention in the EI Technology Centres and in the SFI Research Centres. Only business in the sectors served by Tyndall, NIBRT and Teagasc have access to these services. Other businesses have not.

Section 6.3 will show that the overseas centres have a different approach from the Irish centres. The SFI Research Centres are engaged in a higher level of oriented basic research than the overseas organisations. They may be well placed for delivering oriented basic research. However, as a consequence, the SFI Research Centres can spend fewer resources on short-term applied contract research than do the Fraunhofer Institutes and the Catapult Centres (both in absolute and in relative terms). This also applies to resources spent on contact research. The EI Technology Centres have a profile that to some extent resembles the Belgian SOCs with a strong focus on medium and short-term problem-oriented research, although their size is of very different magnitude.

Overseas organisations seem to invest relatively more in short-term applied contract research, as well as in contract research services, than the EI and SFI centres and the sector-oriented centres in Ireland.

5. Demand side: what research capacity does industry in Ireland need?

The previous chapter presented the current state of Ireland's market-focused research capacity. It showed that public investment in market-oriented RDI through the EI/IDA and SFI centres seem to be allocated at the lower technology readiness levels. The EI/IDA Technology Centres themselves operate relatively closer to market, yet their size is small. SFI research centres currently focus on TRL 1 to TRL 3. Sector-specific centres (Tyndall, NIBRT, and Teagasc) operate across a broad TRL spectrum and therefore also closer to market entrance, yet it must be clear that their direct added value for Ireland is limited to their specific client base. The centre directors expect some change, but this is marginal. When it comes to research function performed, the market-oriented centres in Ireland (both the EI/IDA and SFI centres, as well as the sector-oriented centres) focus on medium term problem-oriented research (including collaborative research). In addition, the SFI centres also invest substantially in basic oriented research. Even though data were presented as shares of core funding, our findings in the previous chapter give little reason to assume that private cash co-funding is used by the centres differently.

The chapter at hand looks at the industry needs in Ireland. It investigates how the demand of Irish-based firms is structured in terms of types of research, development and innovation (RDI) using the TRL and function based approach used earlier in Chapter 4, and it will compare this demand-side picture with the results from the supply side analysis to arrive at a tentative estimate of a possible 'gap'. Throughout, we will identify differences across sectors and priority areas.

Most of the data are based on an electronic questionnaire distributed among the ABSEI RD&I performing population (total of 1708 firms in Ireland). That implies that the group surveyed is larger than the client base of SFI Research Centres and EI/ IDA Technology Centres. In total we received 337 valid responses to our survey (response rate of ±20%). The survey was linked with ABSEI RDI expenditure data to be able to get insight into expenditure patterns in terms of actual monetary volumes. This provides a solid basis for analysing the patterns of the RDI demand side in Ireland, especially given the response rate was reasonably well distributed among different RDI-expenditure bands, Irish-owned and non-Irish owned firms. Due to the constraints on the timing of this questionnaire and data access issues, it was not possible to calculate a fully weighted and expenditure-adjusted representative data set for this analysis. Where relevant, we have scaled expenditure amounts to Irish-system size using widely accepted ABSEI aggregate figures, but we also present average unweighted percentage-based distributions if more appropriate. As a consequence of these methodological challenges, these results should be interpreted tentatively and in terms of general trends, not exact estimates of actual spending. However, we do believe these results constitute robust findings on overall RDI demand spending and trends, which is the objective of this study. We investigate the demand side of RDI provision using two main perspectives. These are presented in Figure 19.

Figure 19 The two main perspectives used to assess the needs of industry in Ireland in terms of research capacity and the extent to which this is currently offered

Current market position of market-oriented research centres:

- *What is the current market for RDI services in Ireland: what do Irish-based companies spend on external RDI in Ireland?*
- *Where do they spend their external RDI budgets?*
- *On what type of RDI do they spend it?*
- *What is the market share of the current market-oriented research centres?*
- *What are expected future developments?*

Unmet demand in the Irish system

- *Does the Irish system as a whole meet companies' RDI demands?*
- *What are drivers and barriers for outsourcing RDI in general and to Irish market-oriented research centres in particular?*

These two perspectives are restructured into five components. These, and the main findings for each of the components, are presented in the figure below together with the main findings per component.

Figure 20 Components of the assessment of the needs of industry in Ireland in terms of research capacity and the extent to which this is currently offered

Component	§	Main findings
Destination of external RDI expenditures from industry in Ireland	5.1	1. There is a significant market for outsourced RDI from Irish companies, totalling €765m in 2013, which industry expects to increase. Irish-owned firms are responsible of 21% of this. 2. Companies indicate that they spent on average 15% of their external expenditure at the Irish market-oriented research centres (representing €100-120m).[67] 3. Irish companies spend over one-third of their external RDI outside Ireland, while Irish research centres attract relatively little investment from abroad, creating an '*RDI trade deficit*' for Ireland. 4. Typically, outsourcing is lowest among ICT (11% of total spending), and highest in modern manufacturing (23% of total spending)
RDI expenditure across TRL levels and research functions by industry in Ireland	5.2	5. Companies spend yearly €2.8bn on RDI[68] (sum of internal and outsourced), of which 16% on TRL 1-3, 26% on TRL 4-5, 26% on TRL 6-7 and 31% on TRL 8-9. Highest outsourcing is in the category TRL 4-5, for a total of between €250-300m annually. Lowest outsourcing in the category TRL 8-9, with a total expenditure of between €100-150m. 6. Companies have the strongest demand (around €400m in 2013) for short-term applied research and for contract research services (€200m).
RDI expenditure across sectors and priority areas by industry in Ireland	5.3	7. Expenditure patterns and volumes differ enormously across sectors. Chemicals, computer electronics and optical products and medical device manufacturing are the three largest sectors in terms of external RDI expenditure, and also have relatively high outsourcing shares (a quarter of their RDI expenditures). Computer programming is also a relatively large RDI sector, yet it has a much lower outsourcing share. 8. Sectors: Chemicals and computer, electronic and optical products have a relatively high demand for contract research services and short-term applied research 9. Priority Areas: Medical Devices and Diagnostics, as well as the Pharmaceutical areas (correlating with the large chemical sector) are relatively focused on contract research, whereas ICT and energy-related topics are focused on basic oriented and medium term research.
Opportunities for research centres 1: Integral analysis of supply and demand.	5.4	10. There is a large market for short-term applied research and contract research services (together over €500m annually), of which less than €10m is spent at the Irish market-oriented research centres. This goes with a strong opportunity to increase the supply of middle and higher TRL levels 11. The market share of market-oriented research centres in short-term applied research and contract research services is likely to

[67] Our supply side analysis shows that centres only receive about €40-€50m from companies annually.

[68] Based on ABSEI data.

Component	§	Main findings
		increase between 2013 and 2018 but ceteris paribus remains less than 2%. 12. Priority areas with a particularly large potential in terms of total external RDI volume are the ICT-related areas, Medical Devices and Therapeutics within the Health-related areas and Manufacturing/process technology areas. Current associated "market shares" of the total set of publicly-funded centres is generally around 5% except for a few smaller priority areas such as Food for Health
Opportunities for research centres 2: Assessment of any unmet demand for market-oriented research capacity in Ireland	5.5	13. A majority (59%) of companies experience a shortage of facilities for testing and experimental development in Ireland. 14. Very few companies' RDI outsourcing needs are fully met by the Irish publicly-funded research centres, but a large group (around 45%) sees their needs at least partly met. 15. RDI performing companies in Ireland seem best served in the medium & short-term problem-oriented research, and are relatively less well served in contract research services and oriented basic research. 16. Around half of RDI-performing companies in Ireland report to have strong interest in increased availability of applied/market-oriented research in Ireland, and could double their RDI external expenditure. A large majority of foreign-owned companies (71%) indicate that such an increase in availability could have a significant impact on their global RDI strategy in favour of Ireland as a destination for RDI.

Source: Technopolis Group

5.1 Destination of external RDI expenditures from industry in Ireland

The figure below presents the key data on RDI expenditure by Ireland-based firms (BERD), based on the annual business survey ABSEI. In 2013, Irish companies have outsourced €765m of RDI expenditure, of which €149m is spent by Irish-owned firms and €617m by foreign-owned firms. A rough extrapolation towards 2018 (using the average annual growth rate of ±7% in the last 10 years) shows that in five years the total outsourced amount will surpass the €1bn mark.

Figure 21 RDI expenditure by Irish companies

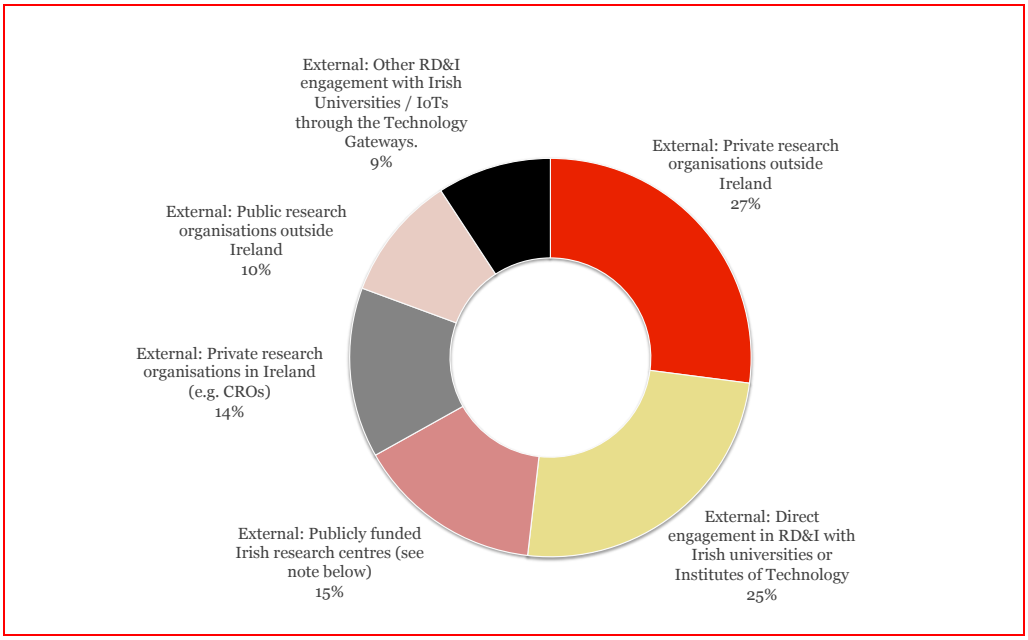
	In-house	Outsourced	Total
RD&I Expenditure (€m) 2013			
Irish-owned firms	653	149	802
Foreign-owned firms	1 445	617	2 061
Total	2 098	765	2 863
RD&I Expenditure (€m) 2018			
Total	±3000	±1000	4000

ABSEI 2013; Technopolis Estimates

The average company in our sample indicates that they spend 16 per cent of their total expenditure externally, in contrast to the ABSEI figure of around 25 per cent. The difference is most likely explained by the fact that a few very large RDI spenders not in our survey skew the aggregate results towards a higher total (a small number of foreign-owned firms).

The figure below shows the distribution of external RDI expenditure destinations (self-reported). Around half of the expenditure is oriented towards the Irish public system, of which 15 per cent is spent at Irish market-oriented research centres (which would represent in the order of magnitude of €100 - 120m). Over a third (37%) of expenditure is spent outside Ireland. Around half of the companies have collaborated or worked with a university or IoT, while only 10 per cent has ever worked with an SFI centre.

Figure 22 Destination of external expenditure (% of responding companies)



Source: Technopolis Group

As is not completely unexpected, Irish-owned companies spend relatively less outside Ireland (3.7% of total expenditure), whereas foreign-owned firms spend around 7 per cent of their total expenditure abroad.

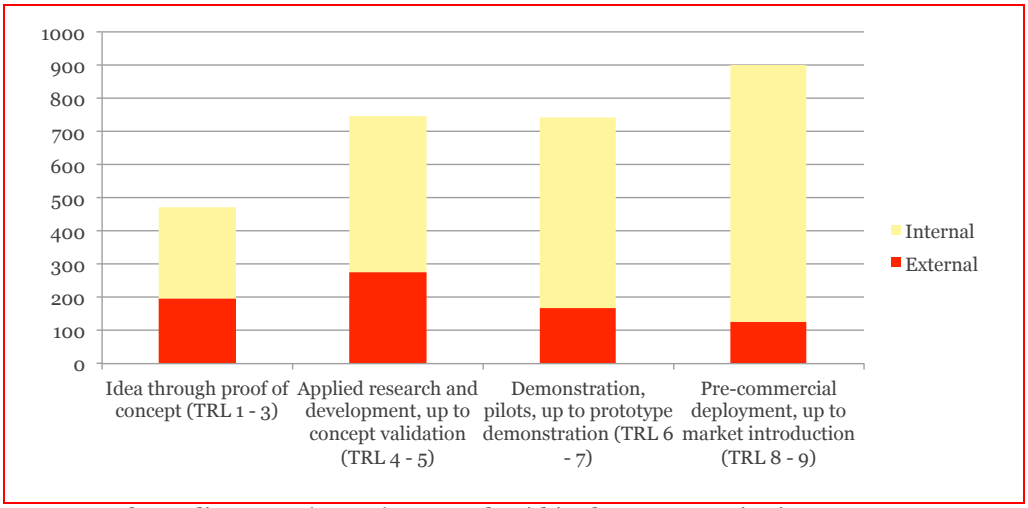
One can conclude that there is a significant market for outsourced RDI from Irish companies, totalling €765m in 2013, which is expected to increase to around €1bn in 2018. Irish-owned firms are responsible of 21 per cent (€149m) of this spending; foreign-owned firms cover with 81 per cent the large majority of external spending (€617m). Companies indicate that they spent on average 15 per cent of their external expenditure on the Irish market-oriented research centres (representing €100-120m). However, our supply side analysis shows that these centres only receive about €40-€50m from companies annually.[69] Irish companies spend over one-third of their external RDI outside Ireland, while Irish research centres attract relatively little investment from abroad, creating an 'RDI trade deficit' for Ireland. Patterns are quite similar for ownership, except that non-Irish firms spend more outside Ireland (7% of total expenditure versus 3.7% of total expenditure on average). Typically, outsourcing is lowest among ICT (11% of total spending), and highest in manufacturing (23% of total spending)

[69] Our survey data do not allow us to elaborate on the balance.

5.2 RDI expenditure across TRL levels and research functions by industry in Ireland

An important factor in understanding RDI expenditure pattern is the technology readiness levels companies spend their resources on. The figure below presents a scaled aggregate of RDI expenditure across categories of TRLs. As could be expected, companies spend more on higher TRLs than on lower TRLs due to the increased uncertainty of investing in this type of research. Highest spending is on pre-commercial deployment (TRL 8-9). Outsourcing is highest for applied research and development (TRL 4-5) and early TRL type of research (1-3). The non-weighted analysis of percentage shares confirms the overall pattern of expenditure.

Figure 23 Private RDI spending across TRL categories by Irish based companies (2013)



Source: Technopolis Group (survey). Internal: within the own organisation or parent company (potentially overseas). External: outside the own organisation or parent company.

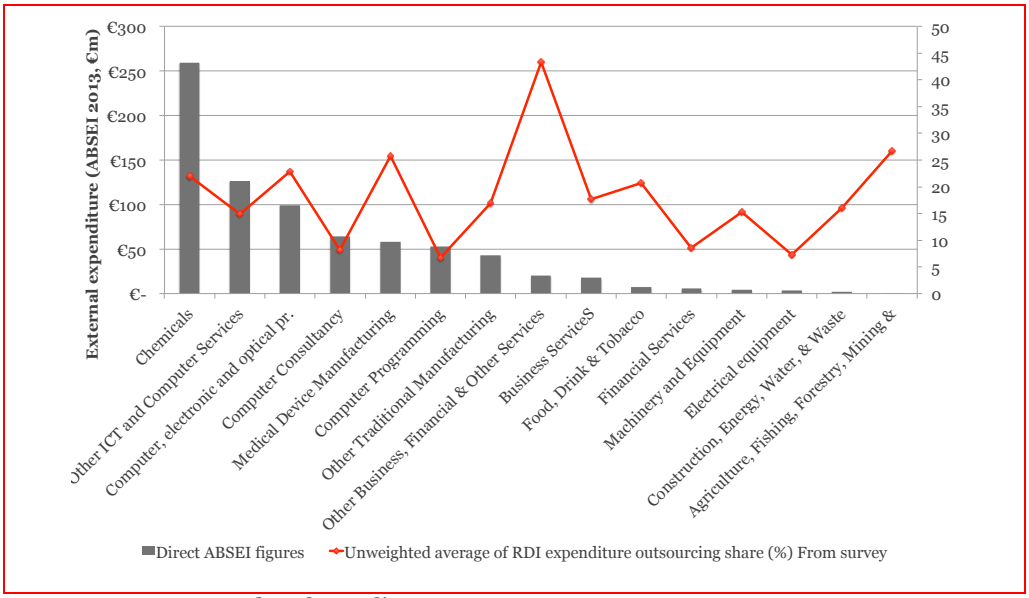
In addition to the TRL analysis we have also asked companies about their external expenditure in terms of research services research centres can provide to companies. Here we see clearly that companies demand for applied, short-term contract research is by far the highest, with contract research services just behind. The 2018 projection shows a similar profile although with higher expenditure on all categories.

It is interesting to note that foreign owned firms and Irish-owned firms have quite divergent RDI type needs. In general, foreign-owned firms focus much more on high TRL such as TRL 8-9 than Irish firms (40% compared with 30%) and on applied and contract research in terms of research functions compared to Irish-owned companies. Foreign-owned firms spend relatively little on orientated basic research (just 9% of total external expenditure).

5.3 RDI expenditure across sectors and priority areas by industry in Ireland

Expenditure patterns and volumes differ substantially across sectors. The figure below shows that the chemicals (which includes pharmaceuticals), computer electronics and optical products and medical device manufacturing are the three largest sectors in terms of external RDI expenditure, and also have relatively high outsourcing shares (between 20 and 25%), indicating that external spending and collaboration are important elements in their overall RDI strategy. Computer programming is also a relatively large RDI sector, but has a much lower outsourcing share.

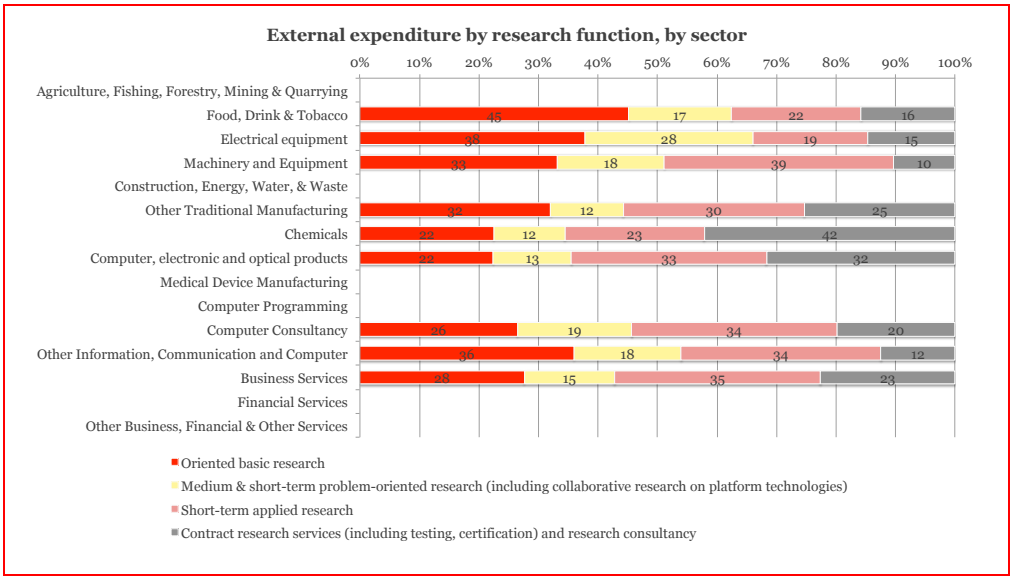
Figure 24 RDI outsourcing by sector-15



Source: ABSEI 2013 and Technopolis survey.

We can also identify the expenditure across sectors (where enough data points were available). The figure below shows that two of the largest sectors in terms of external RDI, chemical and computer, electronic and optical products have a relatively high demand for contract research services and short-term applied research.

Figure 25 External expenditure by research function, by sector



Source: Technopolis Group; RDI survey; ABSEI data (2013)

A similar analysis by research priority area shows that the differences between priority areas in terms of their RDI outsourcing profile are substantial but not extreme. Medical Devices and Diagnostics, as well as the Pharmaceutical areas (correlating with the large chemical sector) are relatively focused on contract research, whereas ICT and energy-related topics are slightly more focused on basic oriented and medium term research than other areas.

Figure 26 External expenditure by research function, by priority area

Source: Technopolis Group; RDI survey; ABSEI data (2013)

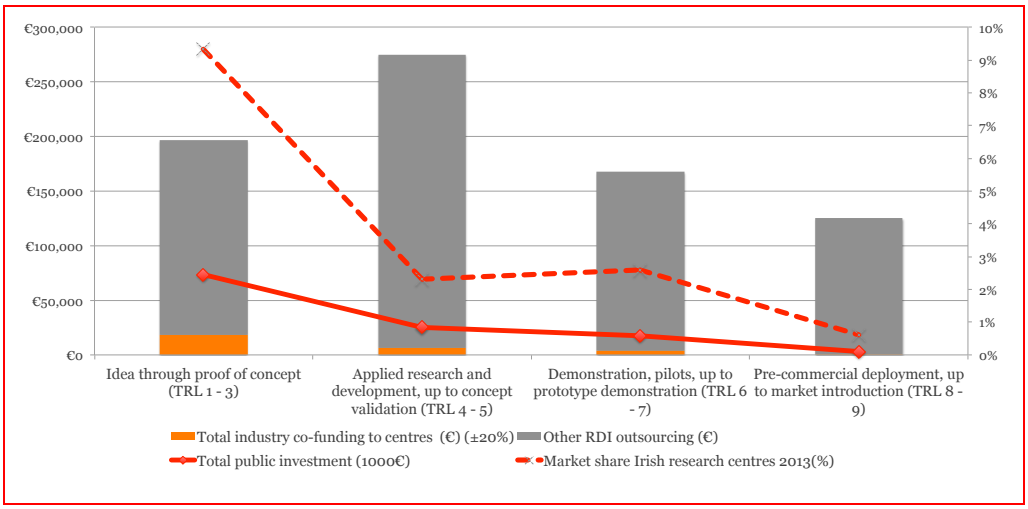
Companies in Ireland spend yearly €2.8bn on RDI (based on ABSEI), of which 16 per cent on TRL 1-3, 26 per cent on TRL 4-5, 26% on TRL 6-7 and 31 per cent on TRL 8-9. Highest outsourcing is in the category TRL 4-5, for a total of between €250-300m annually. Lowest outsourcing is in the category TRL 8-9, with a total expenditure of between €100-150m. Foreign-owned firms are more oriented at late TRL 8-9 (40% compared to 30% for Irish firms), whereas they spend less on TRL 1-3 (13% compared with 23%). Looking at research functions, companies have a strong need (around €400m in 2013) for short-term applied research and for contract research services (€200m). Foreign-owned companies focus more on applied and especially contract research (the latter 45% versus 33% for Irish firms), and less on oriented basic research (9% versus 27% for Irish firms)

Over half of external RDI originates from three sectors: chemicals (including pharmaceuticals), computer, electronic & optical products and medical devices. These sectors are also relatively active in external RDI as they are spending around a quarter of their total RDI expenditure externally. The priority area themes of Pharmaceuticals and Medical Devices & Diagnostics have a stronger focused at the applied (contract) research type of research services; whereas ICT-related areas' expenditure is more balanced across the different types of RDI functions.

5.4 Opportunities for research centres 1: Integral analysis of supply and demand

The best way to assess the opportunities or need for more market-oriented research by publicly-funded research centres in Ireland is to carry out an integral analysis of supply and demand. This allows for the estimation of a 'market share' of the Irish market-oriented research centres, which gives insight in the potential for growth in specific areas of research, development and innovation activities. The figure below presents the key results for the demand & supply analysis in terms of TRL levels.

Figure 27 RDI Outsourcing by TRL, supply & demand (absolute figures *1000)



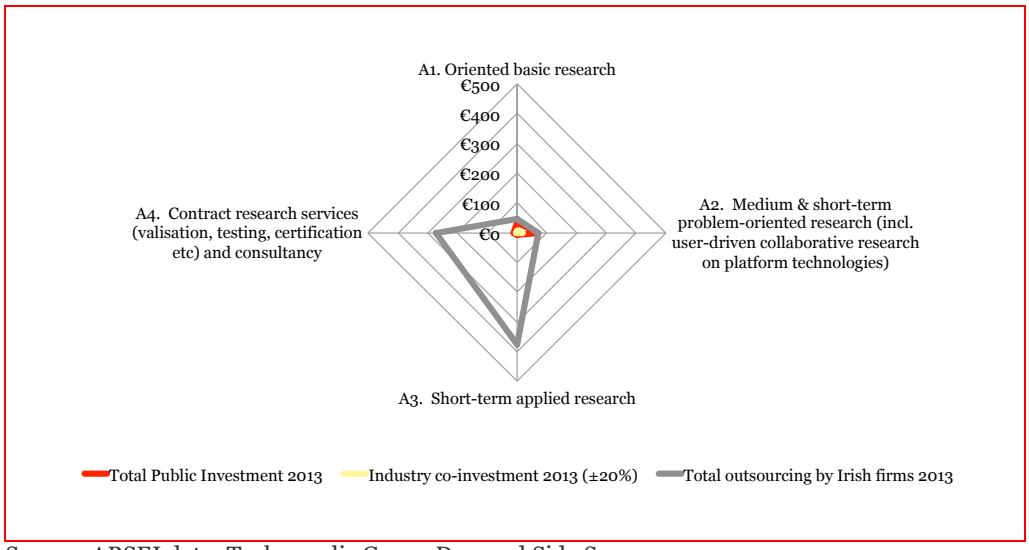
Source: ABSEI data; Technopolis Group Demand Side Survey (2013)

Figure 27 shows that the market-oriented research centres have a high market share (9%) in the low TRL levels (1-3), but have a very small market share in the upper middle and high TRL levels (less than 1%).

Irish-owned companies expect a growth of between 10-20 per cent in the next three years, whereas foreign-owned firms on average expect a growth between 0 and 10 per cent. Since Irish-owned firms start from a much lower base in terms of RDI spending, the aggregate effects of this change on the total composition of RDI expenditure will be likely to be relatively limited, but over time this could result in a stronger home-grown RDI base. This is highlighted by the fact that 20 per cent of Irish firms expect a growth of 30 per cent or higher in the next three years, whereas only 9 per cent of foreign firms report the same bright prospects.

A similar analysis has been carried out in terms of research functions. The figures below show that the results here are even more striking. The first figure shows an estimated total of external expenditure by research functions combined with the levels of public investment and the levels of industry co-investment in 2013. Clearly, there is a high demand for short-term applied research (A3) and contract research functions (A4), which is currently not provided by the market-oriented research centres.

Figure 28 RDI outsourcing & public investment by research function (in €m, 2013)



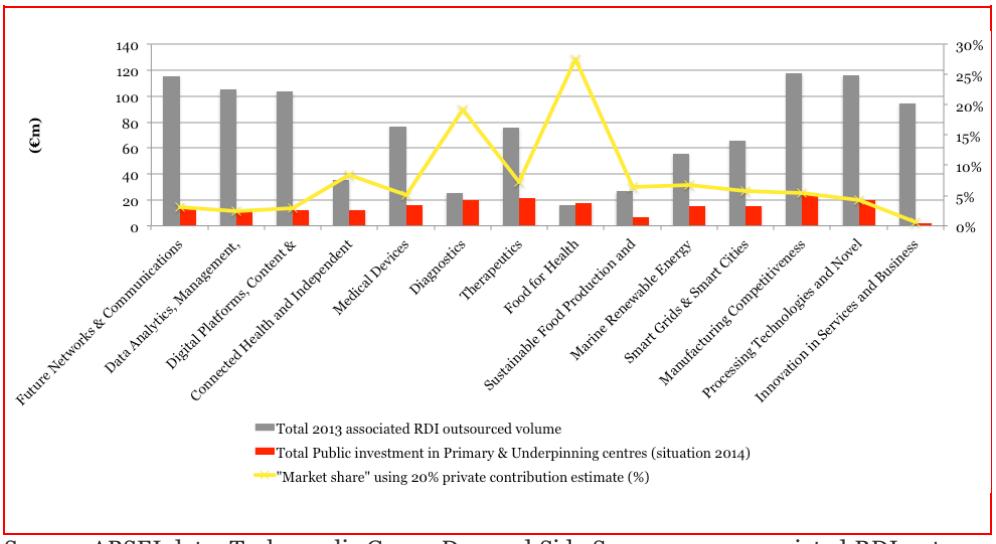
Source: ABSEI data; Technopolis Group Demand Side Survey

The market-oriented research centres in Ireland have a very strong position (25% market share, rising to 30% in 2018) in the category of collaborative research on platform technologies (medium/short-term problem oriented), a strong position in the area of oriented basic research, but very low market shares in the areas of applied research and contract research services.

From the perspective of roadmap development is it important to also gain more insight into the differences across priority areas. The figure below shows an overview of associated external RDI expenditure by companies in Ireland next to the associated public spending through the market-oriented research centres.[70] Using this information, it is possible to construe an estimated "market share" of the set of publicly-funded research centres in Ireland. Naturally, this analysis cannot be construed as an exact estimation of a gap between availability of publicly supported RDI at the market-oriented research centres and private demand, but it does reveal a number of large trends.

[70] Since both companies and centres can operate in more than one priority area, these figures cannot be interpreted as net amounts. We therefore refer to 'associated expenditure'.

Figure 29 Supply/demand by priority area[71]



Source: ABSEI data; Technopolis Group Demand Side Survey. 2013 associated RDI outsourced volumes based on 20% average assumption.

The current set of research centres appear to have a good coverage of the Food for Health and Diagnostics, possibly also because these topics touch on a lot of research centres' activities. Within the priority areas, ICT-thematic areas and manufacturing (including process technologies) are areas where the current set of research centres is involved in only a very small share of firms' total external RDI activities. Within the Health-related areas, Medical Devices and Therapeutics have the most potential in terms of total volumes, the energy & sustainability areas are somewhere in between.

One can conclude that Irish publicly-funded research centres have a good market share in early TRL research (±9%), but relatively low on TRL 4-5 and TRL 6-7 (between 2 and 3%), and a negligible market share on high TRL (8-9). Given these market shares, there seems a strong opportunity to increase the supply of middle and higher TRL levels. Irish companies expect an average growth between 10 – 20 per cent, foreign between 0 – 10 per cent. There is a large market in short-term applied research and contract research services (together over €500m annually), of which less than €10m is spent at the Irish market-oriented research centres.

The Irish market-oriented research centres have a strong position in oriented basic research (between 15 and 20%) and especially in medium & short-term problem-oriented research (including collaborative research on platform technologies) (over 25%). The market share of these research centres in short-term applied research and contract research services is likely to increase between 2013 and 2018 but remains less than 2 per cent.

Priority areas with a particularly large potential in terms of total external RDI volume are the ICT-related areas, Medical Devices and Therapeutics within the Health-related areas and Manufacturing/process technology areas. Current associated 'market shares' of the total set of publicly-funded centres is generally around 5 per cent except for a few smaller priority areas such as Food for Health.

[71] This analysis is based on the situation mid-2014 when the supply side analysis was carried out. This means that some Strategic Research Clusters and Centres for Science, Engineering and Technology were still included while some newly opened SFI Research Centres were not included yet.

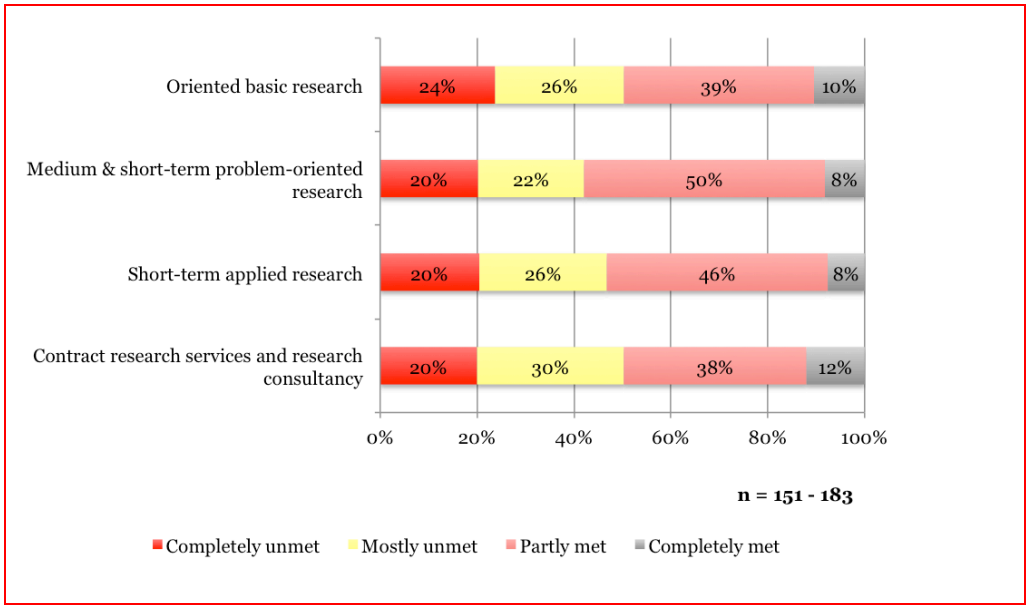
5.5 Opportunities for research centres 2: Assessment of any unmet demand for market-oriented research capacity in Ireland

The second important strategy of demand side analysis pertains to the hypothesis that Ireland-based companies may spend less on outsourced RDI than they would have wanted to due to a lack of the right RDI services and products available in Ireland. Not all companies have the capability of sourcing RDI globally, and even if companies do, a lack of availability of specific RDI functions nearby may deter them from engaging more in RDI altogether.

While it is difficult to assess the exact size of this 'untapped' demand, our industry survey did ask respondents several questions on whether the Irish system and the Irish public research centres in particular could meet their RDI needs.

The figure below shows that only a very small share (around 10%) of companies indicate that Irish publicly-funded research centres meet their RDI needs completely, but a large share (around 45%) indicates that they do or could meet their needs at least partly. Around a fifth of companies indicate that their needs are completely unmet, and another quarter of companies indicate that their needs are mostly unmet. There is relatively little variation across research functions, although companies seems best served in the medium & short-term problem-oriented research, and are relatively less well served in contract research services and oriented basic research.

Figure 30 Perceptions of Irish industry on the market-oriented research capacity in 2014



Companies were also asked to respond to a number of statements regarding their RDI outsourcing needs, which reveal some important qualifying information. First, a large group of companies (40%) indicate that the Irish system as a whole cannot fully provide for their RDI outsourcing needs, pointing towards that the unmet demand by Irish publicly-funded centres is not necessarily covered by other actors in the Irish system. Respondents confirm that they would be interested in their sector for more application-focused public research (58% agrees), and around half of the respondents (48%) indicate that their firm could double external expenditure on RDI in Ireland in three years if the type of RDI services offered by the Irish publicly-funded research centres would be better aligned to their specific needs.

Of foreign companies, 71% indicated that an increased availability of applied RDI in Ireland could have a substantial impact on their companies' global RDI strategy leading to more RDI expenditure in Ireland.[72] A majority of respondents (59%) also indicated that they experience a shortage of testing and demonstration facilities in Ireland.

Firms were also asked to provide open comments on their views on the current and future market-oriented research centre system in Ireland. Even though the survey reported that a large majority (85%) indicates that Irish publicly-funded research centres were in general 'responsive to their needs' at the lower TRLs, actual cooperation and outsourcing with these centres is often hampered by various issues they are dealing with when (attempting to) work with these research centres. The table below gives an overview of the identified issues and their occurrence.[73]

Figure 31 Recurring issues in the open responses

# mentioned	Issue
15	Lack of transparency, difficult to identify opportunities with and outputs from publicly-funded research centres, e.g. need for a one-stop-shop
14	Research centres have a strong culture of focusing on academic goals (PhDs, publications) instead of market orientation and commercialisation expertise
10	Working with Irish research centres is difficult or even impossible due to their IP policies
9	Irish research centres have no interest/are not capable of in doing applied short-term contract research
8	Research centres are not professional/cannot operate within a company timeline (e.g. missing deadlines, inflexibility, fast turnaround)
4	RCs are 'behind', reinvent the wheel and cannot compete with industrial RDI.
4	Required expertise or level of excellence is not available within Irish research centres forcing us to go abroad
3	The Irish RCs are too expensive (in terms of value for money), mostly due to overhead
3	Lack of testing/demonstration facilities
3	Companies have not enough input in the research agenda
3	There is no interest in SMEs, Irish research policy is only focused on large companies
2	Lack of appropriate contract-research oriented accreditation in Irish publicly-funded research centres
2	Inflexible access to research facilities hampers collaboration
2	Lack of practical market orientation with Irish public research centres
1	Lengthy/complex administrative procedures

The findings of the survey indicate that despite efforts to showcase expertise in Irish research centres to enterprise, and efforts by Knowledge Transfer Ireland (KTI) to increase transfer of technology, ideas and expertise to the market difficulties in engaging with the research base are still experienced. Companies surveyed would welcome increased industry culture in centres and further assistance in engaging with Irish research centres. They also commented on a strong academic culture in research centres , and the scope to further improve access to intellectual property. . The need for increased availability of short-term applied research services and testing and demonstration facilities was highlighted.

[72] For a full overview of the survey data see Appendix X

[73] Note: There were also a few (around 5) positive comments, noting either good experience with working with a specific research centre or praise for EI's Voucher and other programmes in helping their companies to access external RDI in Ireland.

One can conclude that very few companies' RDI outsourcing needs are fully met by the Irish publicly-funded research centres, but a large group (around 45%) see their needs at least partly met. RDI performing companies in Ireland seem best served in the medium & short-term problem-oriented research, and are relatively less well served in contract research services and oriented basic research. Around half of RDI-performing companies in Ireland report to have strong interest in increased availability of applied/market-oriented research in Ireland, and could double their RDI-external expenditure.

A large majority of foreign-owned companies (71%) indicate that such an increase in availability could have a significant impact on their global RDI strategy in favour of Ireland as a destination for RDI. Also, a majority (59%) of companies experiences a shortage of facilities for testing and experimental development in Ireland.

6. Inspiration from overseas: features of competitive market-focused elements of research landscapes internationally

The previous section discussed the need for market-oriented research capacity in Ireland. It showed that there is a large market for the provision of external RDI services to Irish companies, expected to grow to over €1bn in 2018, especially in upper-middle and high TRL areas and short-term applied and contract research. Market shares in short-term applied and contract research are currently very small (<2%). This is not surprising, as for example the SFI Research Centres and the EI/IDA Technology Centres were set up to perform collaborative research. The previous chapter also showed that there is a concrete demand or market opportunity for the supply of more short-term applied and contract research, specifically in the sectors of Chemicals (Pharmaceuticals), Computers, Electronic and optical products and Medical Devices, and in terms of priority areas specifically ICT, Medical Devices and Manufacturing Technology (including process technology) areas.

The chapter at hand presents key findings on the situation in overseas research performing organisations. The findings are based on publicly available data from the respective centres, Eurostat, the Worldbank, the OECD, and Erawatch studies that were drafted by Technopolis Group, the IPTS, KTH, and the Manchester Institute of Innovation Research. In addition, findings are based on insight knowledge and experiences of Technopolis' and external experts, and on interviews with representatives of the organisations presented.

This section uses the following four overseas centres to compare the Irish centres:

1. IMEC in Belgium (Section 6.1.3)
2. The Fraunhofer Institutes in Germany (Section 6.1.4)
3. The Competence Centre Schemes in Sweden (Section 6.1.5)
4. The Catapult Centres in the UK (Section 6.1.6)

In addition, Section 6.4 presents specific characteristics of the four overseas centres above and on TNO in The Netherlands; DTI in Denmark; and the SHOKs in Finland. The selection of these seven organisations results from the project proposal. The subsample of four overseas centres discussed in more detail results from the Expert Group Meeting of 18 September 2014 (where IMEC and Fraunhofer Institutes were selected), and further communication with DJEI (in which the Competence Centres Scheme, and the Catapult Centres were selected). The process of selecting the countries together with DJEI and the Advisory Group is presented in Section 1.2.3.

Figure 32 presents the main findings. Before the details are discussed, Section 6.1.2 presents a macro-level/systems level analysis of the countries. The main findings of the remaining parts of this chapter are presented in the figure below:

Figure 32 Main findings on the market-focused research capacity overseas

Component	§	Main findings
Closeness to market uptake of research conducted in the overseas centres. The state-funded portfolios of the overseas centres in terms Technology Readiness Levels (TRLs).	6.2	1. The EI/IDA Technology Centres have TRL distributions that are in line with those in the Fraunhofer Institutes and (to some extent) the Belgian SOCs. These distributions are relative and do not reflect the much smaller volumes of the EI/IDA Technology Centres. NIBRT has infrastructural investment in pilot scale equipment suitable for higher TRL research activity 2. In terms of TRL distributions, the larger SFI Research Centres can only be compared with the former Swedish Competence Centres. Their focus in terms of TRLs differs significantly from that of e.g. Fraunhofer Institutes, or IMEC.

Component	§	Main findings
Specific research functions. The research activities that overseas centres undertake.	6.3	3. In terms of research functions provided, the EI/IDA Technology Centres have profiles that look like the Belgian SOCs (including IMEC) with a strong focus on medium and short-term problem-oriented research. One should however be aware of the small size of the Technology Centres in comparison with the Belgian SOCs and the fact that the EI/IDA Technology Centres do not have the equipment and facilities of the Belgian SOCs. 4. Regarding research functions provided, the SFI Research Centres spend more resources on oriented basic research than the overseas organisations. On the other hand, the SFI Research Centres focus less on short-term applied research than the Fraunhofer Institutes and the Catapult Centres. This also goes for contract research services. 5. In general, overseas organisations seem to do relatively more in short-term applied contract research, as well as in contract research services, than the EI and SFI centres and the sector-oriented centres in Ireland.
Organisational and ecosystem characteristics of the overseas centres.	6.4	6. Overseas centres are generally significantly larger in size than the SFI Research Centres and the EI/IDA Technology Centres. This gives them useful economies of scale that in Ireland can only be reached by Tyndall and Teagasc. 7. Most overseas centres are independent from HEIs. This allows them to invest in their own capital goods, and to set up their own employment statutes. 8. Most overseas centres have public funding horizons that are significantly longer than 5 years. This allows them to set up long-term investment plans, and offer sustainable career perspectives (and tenure tracks) to promising researchers.

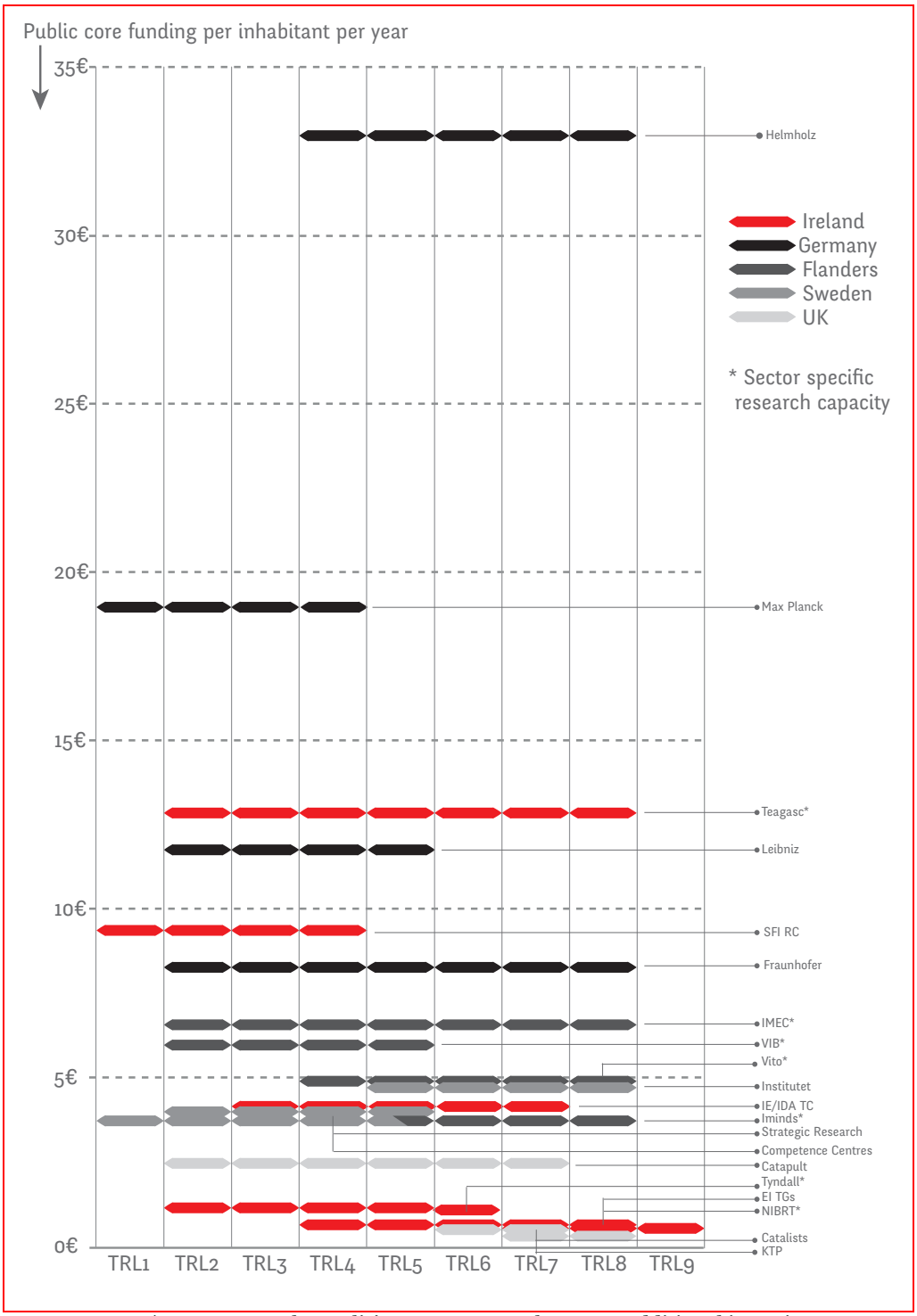
Source: Technopolis Group

6.1 Introduction to the four overseas market-focused research centres used in this section for a more detailed comparison

6.1.1 The presence of research centres Ireland and the four comparator countries

Figure 33 on page 59 gives an overview of the relevant centres in Ireland, and in the four comparator countries. The vertical axis indicates public core expenditures per centre per inhabitant per year. The horizontal axis shows the relevant TRL levels for each of the centres plotted.

Figure 33 Research centres Ireland and the four comparator countries



Source: SFI, EI/IDA, IoTI, Technopolis' experts, external experts, additional interviews

Two main conclusions can be drawn from Figure 33. The first is that in the group of 20 market-oriented research centres plotted in Figure 33 the SFI Research Centres and the EI/IDA Technology Centres are unique. Similar centres that are supported by funding agencies, that range in size from 10 FTE to 100 FTE, that are hosted both physically and legally by universities, that have relatively short-term funding horizons, and that are requested to build sustainable relationships with both research and business, do not exist in the comparator countries.

The second conclusion is that, in terms of public core expenditures per inhabitant, the German market-oriented research centres outperform the other ones. That especially goes for the Helmholtz Institutes and the Max Planck Institutes. Yet, the latter focus on TRL 1 to TRL 4 and have little intention to be market-focused.

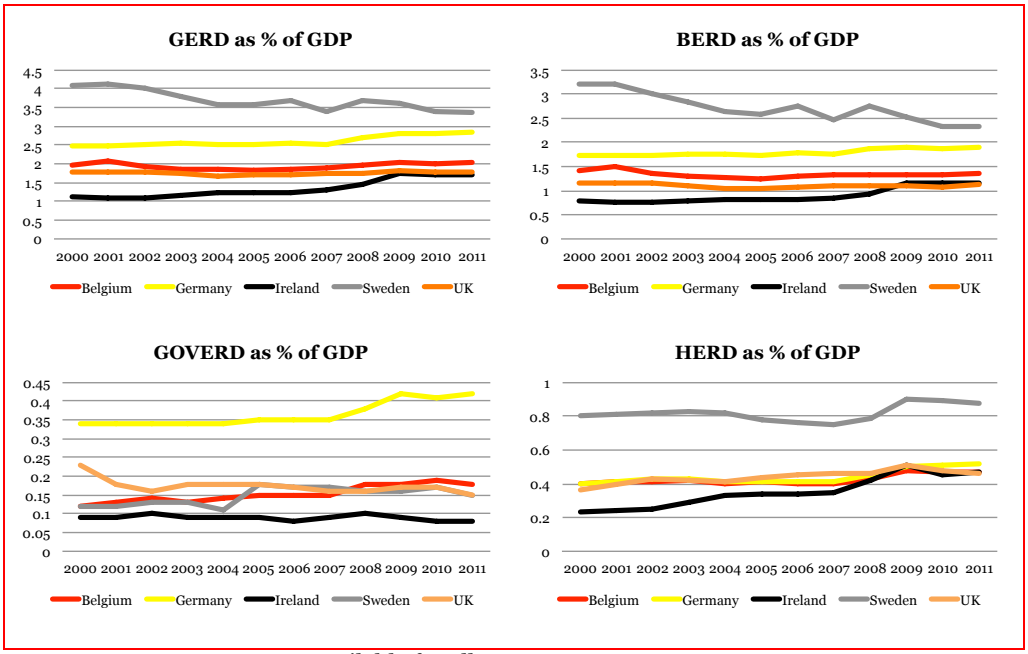
Teagasc is also well funded, and has a clear market orientation, but its research capacities are only available to a small part of the Irish industry. In terms of public core funding per inhabitant, the SFI Research Centres can be compared to the Fraunhofer Institutes, and to the Leibniz Association. Yet, the former covers many more TRL levels, and operates much closer to market. The figure shows that the SFI Research Centres are unique in their focus on TRL 1 to TRL 4. In terms of relative core funding and TRL focus the EI/IDA Technology Centres can be best compared to the Strategic Research Centres in Sweden.

6.1.2 Macro-level comparisons of Ireland and the four comparator countries

The figure below presents historical trend data on gross domestic expenditure on RDI; government expenditure on RDI; business enterprise expenditure on RDI; and higher education expenditure in RDI. All data are presented as percentages of GDP.

On all indicators Ireland seems to be relatively low compared with the other countries. However, the indicators, especially GERD and HERD also show the significant growth that has been achieved in the past decade. Ireland scores relatively 'good' on the HERD indicator, which is due in large part to the significant investment by SFI and the HEA in higher education institutes research centres. Ireland scores low on the GOVERD indicator, which is due to the fact that there is little typical RTO capacity in Ireland. Teagasc accounts for a very large share of GOVERD.

Figure 34 Historical trend data on GERD; GOVERD; BERD; and HERD



Source: EUROSTAT; UK not available for all years

6.1.3 IMEC in Belgium

6.1.3.1 Introduction to Belgium the and Flemish system

The Belgian population is 2.43 times as large as the Irish one. Belgian GDP is 2.29 times the size of Irish GDP. Section 6.1.2 showed that the Belgian GERD as a percentage of GDP is slightly higher than the Irish. Across Belgium business has a smaller role in RDI. Expenditure of HEIs can be compared to those in Ireland.

The Belgian political system, and hence the STI system, is very much a multi-level governance framework that involves the Federal Government and autonomous regional (Flanders, Brussels, Wallonia) and (linguistic) community governments (Flemish speaking, French speaking, German speaking). Belgium is not considered an innovation leader, but it is placed third in the second tier of 'innovation followers'.[74] Both Flemish and Walloon administrations spend considerable resources on encouraging cooperation between the research base and enterprises in Belgium. Efforts to structure and develop specialised market-focused 'clusters' of R&D and innovation have been intensively pursued.

Science and innovation policy in Belgium, particularly regarding the market-focused research centre sector, is however mostly the responsibility of the regional governments rather than the federal government. The example of the SOCs that we present in this chapter is entirely the responsibility of the regional government in Flanders. Relatively much of the research is conducted in public non-profit organisations, which reflects the importance of the SOCs. The Flemish have become aware that it has taken many years for SOCs[75] to become fully operational and realise their objectives, achieve 'critical mass' and attain international recognition.

One of the most important issues in the Belgian system is the need for enhanced coordination between the authorities in terms of the use of financial resources available. The federal government supports the market-focused research capacity through a set of tax incentives. Partial exemptions of advance payment on wages in favour of employers who employ researchers is an instrument of the federal government which offers deductions in wage taxes, under certain conditions, for researchers in public research institutions and private companies.

The Belgian government is very strongly committed to European initiatives, especially the EU Framework programme for RDI, and the ESFRI schemes on research infrastructure. Most RDI instruments are nationally-oriented, yet several are open to foreign businesses. This also applies to the Flemish SOCs that very intensively seek foreign industry to take part in RDI.

Flanders has two main research funders, IWT and FWO. FWO can be compared to SFI, while IWT can be compared to Enterprise Ireland. FWO funds PhD fellowships; postdoctoral fellowships; research grants; projects and mobility. Yet it does not fund centres within HEIs like the SFI Research Centres. IWT funds strategic basic research; post-graduate grants; and post-doctoral research fellowships. It does not fund centres within HEIs like the EI/IDA Technology Centres.

The Flemish system consists of, among other things, several strong universities that are increasingly cooperating with institutes of higher vocational education, and of a series of market-focused research centres (SOCs) of which IMEC is the most prominent. There has been a clear consolidation of smaller universities and third level institutes into larger partnerships with the major universities. One of the rationales of this consolidation was that universities might increase their market orientation.

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74 European Commission (2014). Innovation Union Scoreboard 2014.

75 For instance, IMEC was founded in 1984, VIB (life sciences) in 1995.

The Belgian economy and research and innovation system have faced relatively limited consequences of economic crisis over the last 5 years, especially compared with Ireland. RDI tax reductions for researchers, and tax incentives for business have contributed to the attractiveness of Belgium as an RDI country, both for researchers and for industry.

As in Ireland, MNCs in Flanders are largely foreign-owned. Nevertheless, these MNCs are more active than the EU28 average in terms of both the financing and performing of RDI. Like Ireland, Flanders is also characterised by a large number of SMEs and foreign-owned multinational companies that have their research outside Flanders/Belgium. Compared with their European counterparts, Flemish SMEs are relatively RDI intensive, and have a high absorptive capacity in terms of employment of highly skilled labour (CIS data). Linking research capacities from both the universities to the market-focused research centres to the industry however remains a challenge. Therefore, a set of mainly regional policy instruments were set up, for example the so-called *Innovatiecentra* that received a positive evaluation from Technopolis Group in 2013.

6.1.3.2 Important characteristics of IMEC

IMEC in Belgium is a long-term well-established and well-recognised research organisation that carries out world-leading RTD, subject to regular external evaluations. IMEC is one of the (five) Strategic Research Centres (*Strategische OnderzoeksCentra*; SOCs) in Flanders. SOCs are structured around technologies. All SOCs have different governance models. Each of the SOCs covers all TRL levels in its own domain or technology, however the allocation of efforts and resources across TRLs shows large variations between SOCs, depending on their technological domain. All formally have five-year performance contracts, but at the same time, all are aware that the chances of termination after these five years are almost zero. This is important for investment, commitment, and continuity. Not performing according to the contracts can however lead to possible reductions of the multi-annual budget.

IMEC can be compared to Tyndall to some extent, even though Tyndall is significantly smaller than IMEC. In terms of income Tyndall receives a lower level of core funding (9%) than IMEC (16%).[76] IMEC is a very large industry-focused research centre, without a clear industry base in its home country. Its industry base is global. Client companies are highly RDI intensive, have a history of joint collaboration, and are familiar with very expensive equipment to conduct research (that IMEC has). The main difference between IMEC and an RTO is that IMEC only has joint programmes and rarely engages in bilateral cooperation with individual companies. This reiterates the importance of investment in research infrastructure in certain industrial areas such as manufacturing and microelectronics

While an independent institution with a separate legal status, the collaboration between IMEC and the Flemish universities is quite intensive, particularly with KU Leuven (IMEC is basically on the same campus site as KU Leuven). IMEC hosts and mentors many PhD students who formally get their degree from one of the partner universities. Part-time professorships of IMEC staff are a quite normal phenomenon and university staff can participate in joint projects. Collaboration is often with specific university departments with complementary knowledge in lower TRL levels than IMEC would normally engage in.

[76] Technopolis Group (2012). *Research Centres in Ireland: Funding Models, Oversight Mechanisms and Vision of a Future Research Centre Landscape*. Independent report to Forfás by Technopolis Ltd.

6.1.4 The Fraunhofer Institutes in Germany

6.1.4.1 Introduction to the German system

The German population is 17.55 times as large as the Irish one. German GDP is 17.71 times the size of Irish GDP. Section 6.1.2 showed that the German GERD as a percentage of GDP is much higher than the Irish. A relatively large part of the research is allocated to RTOs, for example the Fraunhofer Institutes, and the Max Planck Institutes. Business has a substantial role in RDI. Expenditure of HEIs on RDI per capita can be compared to that in Ireland.

The German SFI, DFG, funds Research Centres. The primary objective of the DFG Research Centres is to establish a limited number of internationally visible and competitive research centres at German universities. The centres are primarily an element of a university's strategic planning, serving to enhance its research profile and further research priorities. The DFG provides initial funding and support for professorships and independent junior research groups. The centres receive 12-year funding.[77]

RDI policies are high on the German political and policy agendas as a constant strategy over recent decades. That goes for the two important levels of government: the federal state and the regional governments. The STI system in Germany is known for its persistence and straightforwardness. It is widely recognised in Germany that investments in RDI are good investments. Within this context, the key priorities in the German system are: keeping research excellence at a top international level, ensuring/providing sufficient funds for RDI (both public and private), and maintaining and improving the industry-science link. Germany has well survived the crisis of the past five years, mainly due to its strong export sector.

The small number of paradigm shifts in RDI policy can generally be labelled as a shift towards more mission-oriented approaches in technology policy. Important elements of these developments have been the *Pakt für Forschung und Innovation*, which increases funding for the *Helmholtz-Gemeinschaft*, the *Max-Planck-Gesellschaft*, the *Fraunhofer Institutes*, the *Leibniz-Gemeinschaft* and the programmes funded by the *Deutschen Forschungsgemeinschaft* (DFG); the *Excellenz-initiative*, aimed at increasing quality at a number of German universities, and the and *'Hochschulpakt'*. In general these initiatives seek more focus and do not imply funding decreases. They are expected to be continued over the next 7 years at least, which is considered of crucial importance in Germany.

Historically, the partnerships between publicly-funded RDI and industry are well developed. Creating favourable environments for SMEs, as well as MNCs are among the top policy priorities in Germany. There is a wide range of links between publicly-funded RDI and industry, for example in the forms of clusters, ad-hoc cooperation, clusters, and alliances. These relations are strengthened by a clear culture of cooperation between the business sector and pubic RDI organisations. This can be witnessed at institutional level, but also at the level of individual researchers who are very accustomed to spending parts of their careers in businesses.

In addition, the German STI system holds several market-focused research centres and public research organisations more or less dedicated to increasing the market-focused research capacity, for instance the *Fraunhofer Institutes*, specific Technical Universities, and the *Fachhochschulen* (that can be compared to the IoTs, yet are larger in scale and a bit more 'academic' in the work they do).

[77] Source: Deutsche Fonschungsgeeinschaft.

However, there are also clear policy programmes that aim to stimulate the market orientation of publicly-funded research. There is a separate government programme, the SIGNO programme that supports market-focused research centres and the like in implementing ambitious IP policies. The German *High Tech Strategie 2020* also set up several measures to address the need for an the increased focus on SMEs in public RDI programmes and the expansion of the provision of venture capital through *High-Tech Gründerfonds II*, which is a new instrument to support venture. Other measures include *Spitzencluster Wettbewerb* (a competition between leading edge clusters) and the so-called *Forschungscampus*. There are also several thematic RDI programmes (especially in the field of ICT, biotechnology and medical technologies) aimed at achieving fairly specific goals in given technological fields. The majority address innovative firms and encourage their public-private collaboration. There are also initiatives that improve framework conditions for private investment. Nevertheless, it is recognised that Germany needs to improve access to finance for RDI and innovation.[78] For this purpose the federal government established a 'Federal Research and Innovation Funding Advisory Service', which is to serve as the central point of contact regarding RDI cooperation for companies. This agency also aims to make it easier especially for smaller SMEs to get into contact with the large market-focused research centres.

In addition, the German government is especially aware of the need for more investment in HEIs. It has noted that many aspects of its education system are outperformed by other EU/OECD countries and various initiatives to improve this situation have been set up. Investments in market-focused research capacity and in higher education and human capital are far from a zero sum game for Germany.

6.1.4.2 Important characteristics of the Fraunhofer Institutes

The Institutes of the Fraunhofer Society (*Fraunhofer Gesellschaft*, FhG) are a crucial part of the German RDI landscape. There are over 60 Fraunhofer Institutes that generally seek ⅓:⅓:⅓ funding in terms of core funding, publicly-financed contract research and income from private sources. The long-term security of core funding is an important asset for the Institutes; however the Fraunhofer model is highly competitive. The system of core funding channelled through the headquarters in Munich prioritises those Institutes that are more successful and had higher income from contract research activities during previous year. The system enforces the strong institutes and weakens the less successful ones. As a consequence they create competition among the institutes and foster the less successful centres to move away from the areas that create loss and try to re-establish themselves in new areas.

The structure of Fraunhofer is very decentralised and the financial model is strongly market-driven. The Institutes have a high level of independence, but they are not separate legal entities. The Society is a registered not-for-profit association. Each institute is an individual centre with a director overseeing its operation. Whenever a new Fraunhofer Institute is set up it is allowed about 3 to 5 years to get to the required ⅓:⅓:⅓ funding level. The Institutes are subject to five-year performance reviews.

The Fraunhofer Society is very much industry-focused. In that sense it is intrinsically part of the German engineering system and culture. At the same time the Institutes are also closely linked to universities. The close relations are reinforced by the requirement that a prerequisite to becoming a Fraunhofer Institute director is being a full time professor at a university. Other staff also often hold positions at universities, while PhD and undergraduate students are an integral part of the human resources at the Fraunhofer Institutes.

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[78] Technopolis Group (2010). *Evaluierung des High-Tech Gründerfonds.Gründerfonds.* Studie im Auftrag des Bundesministeriums für Wirtschaft und Technologie.

In the German system, IP is generally owned by the employer of the inventor. IP ownership generated from contract and collaborative research activities is defined in the specific contract research and consortium agreements.

6.1.5 The Competence Centre Schemes in Sweden

6.1.5.1 Introduction to the Swedish system

The Swedish population is 2.09 times as large as the Irish one. Swedish GDP is 2.75 times the size of Irish GDP. Section 6.1.2 showed that the Swedish GERD as a percentage of GDP is much higher than the Irish. Relatively much of the research is conducted in Higher education institutes. Businesses also have a substantial role in RDI, which is a consequence of the strong MNC base.

VINNOVA is one of Sweden's four major research funders. It covers some aspects of the work SFI and EI do in Ireland. VINNOVA has specific programmes aimed at SMEs, but none of them aim at establishing research centres.

In terms of RDI investment per capita, and in terms of RDI expenditure as a share of GDP, Sweden is among the highest ranking countries in the world. Regarding the latter parameter, Sweden is the third highest-ranking country. Nevertheless, there has been significant decline, especially in GERD figures, as is clearly shown in Figure 34. This is mainly due to decreasing BERD figures, which can also be seen in that particular graph. The latter decline was caused by several factors, including the closing of research sites in Lund (2010) and Södertälje (2012) by AstraZeneca, and by Sony Mobile's closing of its Lund site in 2012. At a macro level, the Swedes have felt relatively little impact of the 2008 crisis. The consequences were significantly below EU average.

The consensus in Sweden is that the STI system in Sweden is in good shape, yet that there needs to be more focus in certain areas, and that ties between industry and academia need further improvement. Like Ireland, the Swedes spend relatively much of their public expenditures on RDI through the HEIs. In the case of Sweden, this is over 90 per cent. The Swedish universities, via for example the Competence Centres introduced in the following section, have a certain history of working with private organisations. In 2010 there was significant deregulation of the academic sector. At this point in time it is often heard that this deregulation has not yet had a substantial effect in actual practice.

Governmental research and innovation policy is generally based on the assumption that while the research and innovation system is in relatively healthy shape, Swedish long-term competitiveness hinges on strategic profiling and mobilisation in core areas and strengthening of the rather weak interaction between academia and industry. A number of policy measures have been set up in the last couple of years because of this. In 2008 the Swedish Research Bill was presented: as a consequence the Strategic Research Areas were set up. This involved a targeted funding of twenty domains. Four years later, an extra four were added.[79] The Swedish Research Bill also resulted in an increase of block grants for the Swedish universities. The size of this increase becomes clear when looking at Figure 34. At the same time, these block grants are now subject to performance metrics.

[79] In December 2014 this policy instrument is being evaluated.

Additional measures under the Bill target the commercialisation of academic research through strengthening the institute sector and developing TTO structures in universities and in colleges. This was found especially important, as the poor innovation performance of the Swedish economy has been a topic of discussion for at least 15 to 20 years. The main issues that constitute this 'Swedish Paradox' include a deep structural division and separation between the public and industry RDI.

This prevents exchange in terms of human capital, and in terms of academy-industry knowledge transfer. Another issue is that the Swedish public RDI system (*in casu* the Swedish universities) is broadly demarcated, instead of focused and cutting-edge. A third issue is the lack of RDI intensive SMEs, and an over-dependence on large MNCs for industry RDI. The Expert Workshop organised by Technopolis Group clearly showed that most Competence Centres were dominated by MNCs, and that the Swedish government found it hard to find enough SMEs to set up a Competence Centre dedicated to SME RDI.

6.1.5.2 Important characteristics of the Competence Centre Schemes

The Competence Centre Schemes were long-running programmes with substantial industry influence (generally, the industry was the most powerful actor). Specific centres were set up in a very bottom-up manner. The KPIs mainly focused on indicators such as sales, profits, turnover, and so forth. Traditional research-related indicators received less attention. They had relatively long-term funding horizons, they were set up to internationalise (just like their value chains), and they had fair and workable IPR regimes.[80]

Ultimately there were 28 Competence Centres, (preceded by some 300 applications). In 10 years of funding, total budgets were SEK 4.9 bn (approx. €500m), 1.5 bn of which was public money. In total about 200 companies were involved. There was a strong industry influence. Formally the Competence Centres were not RTOs, even though they undertook typical RTO activities. The success of the Competence Centres was partly due to the presence of some large Swedish-based MNCs. They participated intensively in the Competence Centres. Their funding was important, but that also was the case for their absorptive capacities. Moreover, the cooperation of these companies in the Competence Centres did not suddenly appear. Competence Centres operated at the low TRL levels. The current consensus is that there were problems moving away from basic research in the centres themselves, although several of the participating companies were able to take care of and further develop research results into profitable products and processes.

6.1.6 The Catapult Centres in the UK

6.1.6.1 Introduction to the UK system

The UK population size is 13.97 times as large as the Irish one. UK GDP is 12.72 times the size of Irish GDP, and accounts for almost 15 per cent of the total EU GDP. Section 6.1.2 showed that the UK GERD as a percentage of GDP is more or less equal to the Irish figures. This also goes for BERD and HERD figures per capita. GOVERD figures per capita in Ireland are considerably below UK figures. Like Ireland, the UK is an innovation follower. One of its main strengths is the quality of research, whereas the introduction of innovations to the market could be improved.[81]

[80] 'Whatever you own stays yours, what we find together, we own together.' This was however problematic for some smaller companies.

[81] Cf. the *2013 Innovation Union progress report*.

The UK's seven Research Councils fund independent research institutes. In order to receive funding from the Research Councils, these institutes may not be owned; established; or primarily (i.e. 50% or more) funded by the public sector (other than by a Research Council, HEI, NHS Trust, National museum/gallery/library/archive/ botanical garden/observatory) or by a business. The Catapult Centres do not meet these criteria. Yet, centres funded therefore include the British Library, the British Museum, CERN, Chatham House, National Gallery the Overseas Development Institute; Tate; The National Maritime Museum, or the Transport Research Laboratory.

The UK's seven Research Councils do not fund market-focused centres (like the SFI Research Centres or the EI/IDA Technology Centres).[82] Catapult Centres may be named contractors within research grants, and in the case of some Research Councils, their staff may be eligible as Co-Investigators.[83]

The UK economy has been hit hard by economic decline, but was also one of the first ones in Europe to show recovery. The crisis does not seem to have had a direct effect on RDI expenditure. The main funder of public research in the UK is the Department of Business, Innovation, and Skills (BIS). It funds a total of seven Research Councils. They, in turn, support RDI activities in the HEIs, RDI in their own Research Council Institutes (e.g. the British Antarctic Survey, the Laboratory of Molecular Biology, the Roslin Institute and the Rutherford Appleton Laboratory), and RDI in other research performing organisations. This implies that BIS has a spinal role in the UK system, and that the Research Councils implement policy and strategies in their own domains.

There are a number of clear challenges to the market-focused research landscape in the UK. These include a continuing low level of private RDI investment in all sectors of the UK economy. This implies there is a need to improve the translation of the outputs of publicly-funded RDI into commercial products, processes and services. There is a need to maintain a strong policy focus in this regard. Another uncertainty relates to the future HRST base, as higher student fees were introduced in 2012. The third challenge to the supply of venture capital, which is considered too low.

The UK market-focused research capacity policies have remained relatively stable over recent years. The material changes were largely announced in the 2011 Innovation and Research Strategy for Growth. The Regional Development Agencies have been replaced by Local Enterprise Partnerships (LEPs). There has also been an increased targeted support on Key Enabling Technologies (KETs), and an increased availability of support to SMEs that want to invest in RDI. In addition, support is being provided to private sector RDI through tax credits and Innovate UK, formerly known as the Technology Strategy Board. It has four aims: to accelerate the journey from concept to commercialisation; to connect the innovation landscape; to turn government action into business opportunity; and to invest in priority themed areas based on potential. Innovate UK funds, supports and connects innovative British businesses through several programmes, including Collaborative Research and Development, (and also "Smart" for smaller firms), SBRI (the Small Business Research Initiative), Knowledge Transfer Partnerships, Launchpad competitions and overseas missions. Innovate UK also works with the Research Councils to run four Catalysts: Agri-Tech, Biomedical, Energy, and Industrial Biotechnology.

One of its major initiatives is the Catapult Centres. This network of centres is focused on technologies and sectors where the UK stands to gain sustainable economic advantage well into the future. These centres, in which Innovate UK will have invested over £200m by 2015, represent a crucial investment in the UK's innovation infrastructure.

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[82] Source: Research Councils UK.

[83] See ESRC and MRC rules on eligibility for Co-Investigators.

6.1.6.2 Important characteristics of the Catapult Centres

The Catapult Centres launched by Innovate UK support innovation by UK business; there are seven Catapults, each focusing on an area identified as strategically important to the UK (defined sectorial and STI priorities), and which also has large global market potential. Some Catapults have dedicated centres at one location and others have multi-site shared centres.

The Catapults aim at a ⅓:⅓:⅓ funding base, with a requirement also for contract research as part of the financial sustainability of the centres. As part of the concept of the Catapults, all projects happen between technology validation, technology demonstration and prototype demonstrations (i.e. TRLs 4-7), though the mix is variable and dependent on individual centres and projects. The Catapults operate on five-year business plans. One particular strength of the Catapults is bringing together existing centres of excellence and resources, opening access for industry use. Industry guidance is strong, with governance mostly industry-based. Industry co-funding is mainly cash.

Most centres are now 2 to 3 years old, with a couple more recently established. A mid-term review was published in November 2014, chaired by scientific advisor Dr. Herman Hauser, whose initial recommendations in 2010 spurred the creation of the Catapults. This review states that the centres have worked well as 'neutral convenors', and makes nine main recommendations for building on the work to date.

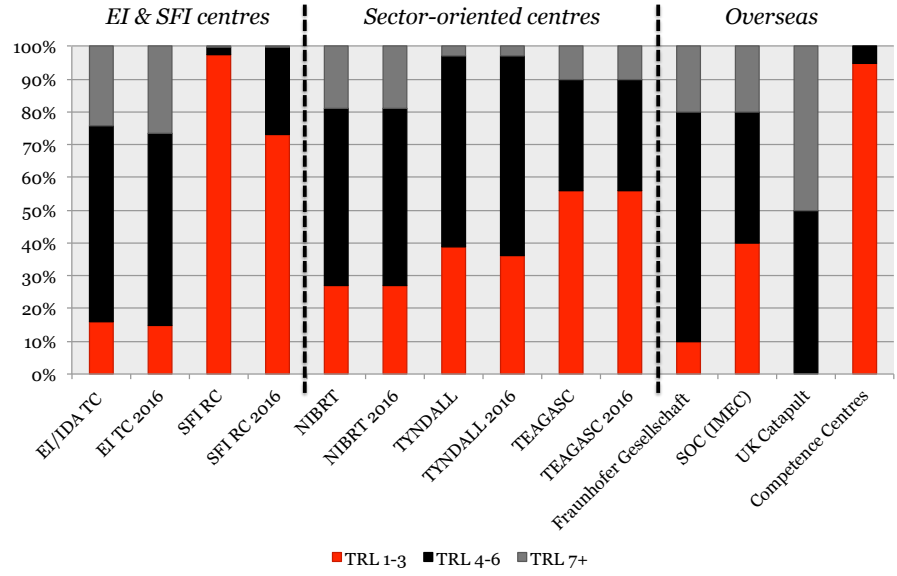
6.1.7 Preliminary success factors as identified overseas

Based on the centres described in this section, one can identify a number of preliminary success factors for the overseas centres that are elaborated in Section 6.4. These include: industry cash contributions; pre-Catapult investments in infrastructures and laboratories; presence of a university to set up intensive collaboration and to pragmatically exchange HR; a clear legal independence of the university to allow operational flexibility that is combined with close peer-to-peer working relationships with universities; a certain size in terms of research FTE to realise sufficient critical mass; long term funding models that allow the centres to invest; and a fair and workable IPR regime.

6.2 Closeness to market uptake of research conducted in a broad set of overseas centres: the state-funded portfolios of the overseas centres in terms Technology Readiness Levels (TRLs)

Section 4.3 showed that the consolidated activities of EI/IDA and SFI centres focus on the lower technology readiness levels. The EI/IDA centres themselves operate relatively close to market, but their size is small. SFI primarily focus on TRL 1 to TRL 3 at present. Sector-specific centres (Tyndall, NIBRT, and Teagasc) operate closer to market entrance, but they can only serve their specific client base. The figure below compares the distributions of resources over the TRLs in the Irish centres with the distributions found in the organisations that were presented in the previous section.

Figure 35 Estimates of allocation of resources to groups of TRLs in Irish centres and in market-focused research centres and research centres in other countries (estimates)



Source: see Figure 14 & Figure 15. Overseas centres based on Technopolis Group, and on external experts

The EI/IDA Technology Centres have distributions that are in line with those in the Fraunhofer Institutes and IMEC but have much smaller volumes. The sector-oriented research centres in Ireland also have distributions that resemble the distributions of typical RTOs like Fraunhofer. But these centres focus on a specific client base and are not of use to the large part of industry in Ireland. The larger SFI Research Centres can only be compared to the former Swedish Competence Centres in terms of TRLs. Their focus in terms of TRLs differs significantly from that of, for example, Fraunhofer Institutes, or IMEC. The UK Catapults are unique in their focus on the high TRLs.

The findings on the EI/IDA Technology Centres, IMEC, and the Fraunhofer Institutes are in line with the view that EARTO has on RTO activities at the respective TRL levels, which is presented in Figure 36. The UK Catapult Centres seem to focus primarily on the higher TRLs. The Swedish Competence Centres and the SFI Research Centres focus on the lower TRLs (1 to 3).

Figure 36 The view of EARTO on RTO activities on the respective TRL levels

'RTOs have a clear role in translating research across the entire TRL scale, in cooperation with existing and emerging industries and academia, from idea to application. Taking an idea from the drawing board through demonstrations, pilots, and practical development hurdles to commercial success requires expertise and infrastructures that RTOs possess and that are heavily used by European industries and national governments already today.'

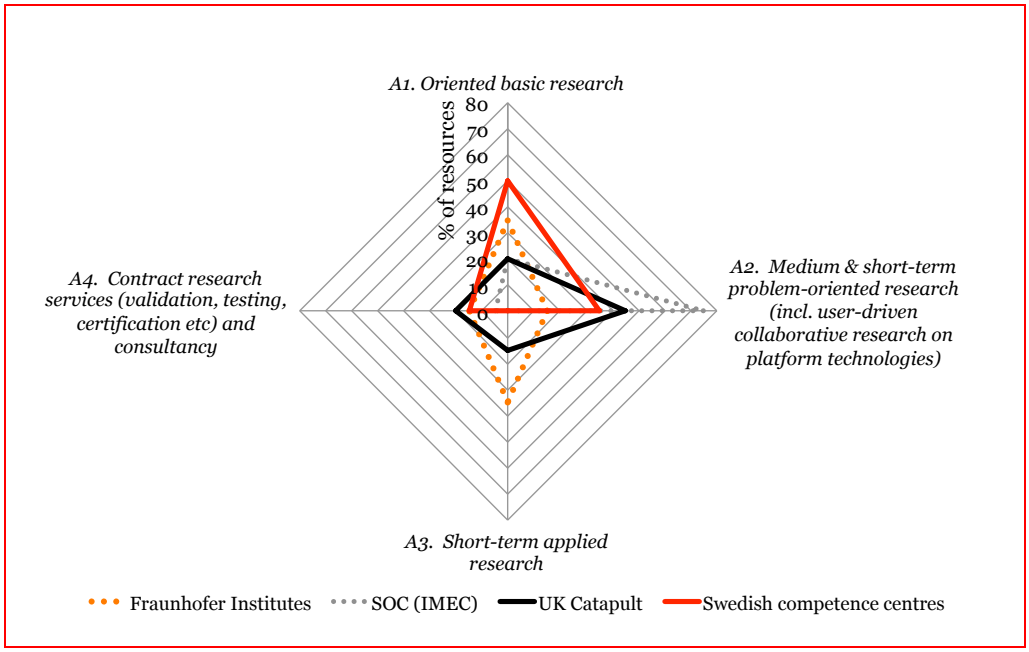
'Realising EU competitiveness and growth objectives requires covering technology development from near-basic research to commercially viable solutions available on the market. This means covering technology readiness from level 1 to 9. RTOs are active at all of these levels and there is ample evidence concerning their contribution in helping industry take the crucial step from one level to another.'

Source: EARTO, 2014

6.3 Specific research functions: The research activities that overseas centres undertake

Section 4.5 showed that research centres in Ireland (both the EI and SFI centres, as well as the sector-oriented centres) invest a large share of their resources in medium & short-term problem-oriented research. In addition to that, the SFI centres also invest substantially in oriented basic research. However, EI and SFI centres as a group spend only small portions of their resources on typical RTO services and market-focused services such as consultancy, contract research services, and short-term applied research. Figure 37 shows the distributions of resources over the research functions in the four overseas centres that we identified in Section 6.1.

Figure 37 Research functions for industry, expert-assessments of priorities per (group of) organisation(s) (reference year: 2014)



Source: see Figure 14 & Figure 15. Overseas centres based on Technopolis Group, and on external experts

The four overseas centres we identified in Section 6.1 seem to have a different approach from the approaches of the Irish centres identified in Figure 17. The SFI Research Centres spend more resources on basic oriented research than the overseas organisations. On the other hand, the SFI Research Centres spend fewer resources on short-term applied contract research than the Fraunhofer Institutes and the Catapult Centres. That also goes for resources spent on contract research. The EI/IDA Technology Centres have a profile that resembles the Belgian SOCs (including IMEC) with a strong focus on medium and short-term problem-oriented research, although their size is of very different magnitude.

The comparison with overseas market-focused research centres makes it clear that these organisations are enabled to invest relatively more in typically RTO-like industry oriented functions, such as short-term applied contract research, as well as in contract research services, than the EI and SFI centres and the sector-oriented centres in Ireland.

6.4 Organisational characteristics and ecosystem characteristics of overseas research organisations

Chapter 4 showed some characteristics of the EI/IDA Technology Centres and the SFI Research Centres. The Irish centres range in size from 10 FTE to 100 FTE. Generally they are part of the Irish university system. Formally they should be seen as 5-year projects financed by EI, SFI, universities, and industry, and run by universities and industry representatives. Section 4.2 showed that compared with their market-oriented overseas counterparts, the Irish centres receive relatively little private co-funding (cash, as a percentage of public core funding).

Figure 38 presents some key findings on the organisational and ecosystem characteristics of seven overseas centre models. It gives an impression of the way overseas centres are set up and how they operate.

Figure 38 Organisational characteristics and ecosystem characteristics of overseas research organisations

Country	Belgium	Germany	Sweden	UK	NL	Denmark	Finland
Organisation	IMEC	FhG	CoC	CaC	TNO	DTI	SHOK
Section with elaborations	6.1.3	6.1.4	6.1.5	6.1.6	n/a	n/a	n/a
Basic characteristics of the model							
TRLs covered	1-7	3-7	1-7	4-6	1-7	3-8	1-7
Centre size (FTE)	2000+	±350/FhI	flexible	10-300	±200	±1000	±500
Relationship with HEI	Peer-to-peer	Peer-to-peer	Very close	Peer-to-peer	Distance	Distance	Distance[84]
Primary industry engagement	Platform	Project	Platform	Mix	Project	Project	Platform
Funding model (app.)[85]	20%-80%	33%-33%-33%	33%-33%-33%	dynamic	33%-33%-33%	15%-85%	60%-40%
Funding Horizon	5y officially, longer in practice	Long-term	10y.	5y.	5y officially, longer in practice	Short term	5-10y
Ecosystem characteristics							
Industry base per country	Mixed	Strong	Strong	Mixed	Strong	Strong	Mixed
System size vis-a-via Ireland	1.5x IE	20 x IE	2x IE	15 x IE	4x IE	1.5x IE	1 x IE
Some important HEI system characteristics[86]	Dual system, in transition	Dual, federal, with a strong centre culture	Strong and well developed tech unis	Semi-dual	Dual, with strong and well developed tech unis	Dual	Dual, with strong and well developed tech unis

Source: Expert Workshop Report

[84] Even though universities do take part in SHOKs.

[85] When 2 figures are given, they represent respectively incomes from public core funding versus private funding and public competitive funding. When 3 figures are given, they represent respectively incomes from public core funding versus private funding versus public competitive funding.

[86] Dual implies the inclusion of substantial amounts of both vocational (skills-based) and higher (academic-based) education in the same institution.

The seven comparator organisations have features that differ significantly from the characteristics of SFI Research Centres and of EI/IDA Technology Centres. These include:

- **Overseas centres used in our comparator analyses are significantly larger in size** than the SFI Research Centres and the EI/IDA Technology Centres. They have a critical mass that is not obtained by the Irish Centres that usually range in size from 10 FTE to 100 FTE. The overseas centres are usually several times larger.[87] This might offer these overseas centres economies of scale that in Ireland can only be reached by one or two sector oriented centres. It should be noted that the current Irish strategy does entail a relatively high number of centres of both types, compared with systems of similar size abroad (e.g. Flanders). Still, the total volume of research conducted in these centres combined is relatively small even when compared to single market-focused research centres abroad (see Figure 12).
- **Overseas centres are independent from HEIs**. They have what was referred to by some of our experts as a 'peer-to-peer relationship' with an HEI, which implies that while the research centre is an independent legal entity it needs a university mainly to make use of certain rights that are traditionally exclusively granted to universities, for example the granting of professorships, or of PhD grades. This peer-to-peer relationship allows the research organisations to invest in their own capital goods, to be flexible when it comes to IP rights and relationships with industry, and to set up their own HR policies and employment statutes.
- **The overseas management can implement their own HR strategies**. This implies that their HR policies are more flexible than the Irish centres, and that they can quickly respond to developments in the domain, to industry needs, or to other developments. Moreover, this allows them to guide and mentor young researchers, offer tenure tracks and long term careers to promising researchers and to attract world-leading researchers.
- **The overseas centres have significantly different funding models**. In general industry contributions are substantial. Typical RTOs, such as the Fraunhofer Institutes (see also Section 6.1.4), and TNO (not included in detailed analyses) have more than 30 per cent industry contributions, most of which is in cash. IMEC receives most of its income from industry, which also goes for DTI.
- **Most overseas organisations have public funding horizons that are much longer than 5 years**. In those cases where the formal funding horizon is 5 years, there is often an informal agreement with funding organisations or other decision makers that centres will survive (even though funding organisations and other decision makers might require evaluations and ask the centre to change strategies accordingly). This long-term horizon, which is not offered to most Irish centres, allows the overseas centres to set up long-term investment plans, and offer sustainable career perspectives (and tenure tracks) to promising researchers.

[87] The only exceptions are some small Catapult Centres (e.g. CellTherapy Catapult). Other Catapults (e.g. High Value Manufacturing Catapult) are significantly larger (about 300 FTE).

7. Synthesis of the current state, key requirements for the future, and possible models and arrangements to meet the requirements

7.1 Summary of current state of Ireland's market-focused research capacity (Chapter 4) and the inspirations from overseas (Chapter 6)

This section explains the main findings from our assessments of Ireland's market-focused research capacity (Chapter 4) and the inspirations from overseas (Chapter 6). The findings are based on the sources identified in Figure 3, including most of our interviews, the data from the SFI Research Centre directors, the EI/IDA Technology Centre directors, and the Stakeholder Workshops.

Total expenditures on the state-funded research centres per inhabitant in Ireland are relatively small compared with expenditures in other countries. At the same time, the Irish state-funded research centres have a high share of public core-funding compared with organisations serving similar research functions in several countries of comparable size, including e.g. Denmark, The Netherlands, Austria, and Belgium. This was shown in Section 4.2.

Section 4.3 empirically showed that the aggregated public investment in RDI through the EI/IDA and SFI centres focus on the lower technology readiness levels (1 to 3). The EI/IDA Technology Centres themselves operate relatively close to market, but their size is small. SFI research centres currently focus on TRL 1 to TRL 3. Sector-specific centres (Tyndall, NIBRT, and Teagasc) operate across a broad TRL spectrum and therefore also closer to market entrance, yet it must be clear that their direct added value for Ireland is limited to their specific client base. Similar assessments were made by our experts and interviewees for overseas centres in Section 6.2. The EI/IDA Technology Centres turn out to have TRL distributions that are in line with those in the Fraunhofer Institutes and (to some extent) the Belgian SOCs. These distributions are relative and do not reflect the much smaller volumes of the EI/IDA Technology Centres. In terms of TRL distributions, the larger SFI Research Centres can only be compared with the former Swedish Competence Centres. Compared with, for example, Fraunhofer Institutes, or IMEC they focus on the lower TRLs.

Section 4.4 assessed the prognoses of Irish centre directors. The EI and the SFI centres expect an increase of activities on TRL 3; TRL 4 and TRL 5. This growth is mainly attributable to prognoses of SFI research centre directors (42% increase in weighted average in terms of TRLs), and to a lesser extent attributable to prognoses of EI /IDA research centre directors.[88] Beyond TRL 5 the EI/IDA and SFI centre directors expect no increase in activities. Irish companies that need research and development that is more mature than TRL 5 depend on the small EI/IDA Technology Centres' capacity, and on sector oriented research capacities in Teagasc, Tyndall, and NIBRT. The sector-oriented centres (Teagasc, Tyndall, NIBRT) foresee small developments in their activities at the higher TRL levels.

Specific research functions provided in the Irish system were assessed in Section 4.5. EI and SFI centres as a group spend only small portions of their resources on typical near-market-focused research and services such as consultancy, contract research services, and short-term applied research. The EI/IDA and SFI centres, as well as the sector-oriented centres, invest a large share of their resources in medium term problem-oriented research (including collaborative research). In addition, the SFI centres also invest substantially in long-term use-inspired basic research. Section 6.3 includes similar assessments for overseas research centres.

[88] 2% increase in weighted average in terms of TRLs.

In terms of research functions provided, the EI/IDA Technology Centres have profiles that look like the Belgian SOCs (including IMEC) with a strong focus on medium and short-term problem-oriented research. One should however be aware of the small size of the Technology Centres in comparison with the Belgian SOCs and the fact that the Technology Centres do not have the equipment and facilities that the Belgian SOCs have. Regarding research functions provided, the SFI Research Centres spend more resources on oriented basic research than the overseas organisations. On the other hand, the SFI Research Centres focus less on short-term applied contract research than the Fraunhofer Institutes and the Catapult Centres. This also goes for contract research services. In general, overseas organisations seem to relatively do more in short-term applied contract research, as well as in contract research services, than the EI and SFI centres and the sector-oriented centres in Ireland.

Chapter 5 investigated the private demand for specific types of research, development and innovation services and products. This showed that there is a large market for the provision of external RDI services to Irish companies, expected to grow to over €1bn in 2018, especially in upper-middle and high TRL areas and short-term applied and contract research. The current market-oriented research centres are strongest in medium-term collaborative research where they have their highest market shares (±10%). Market shares in short-term applied and contract researches are currently very small (<2%). There is a concrete demand or market opportunity for the supply of more short-term applied and contract research, specifically in the sectors of Chemicals (Pharmaceuticals), Computers, Electronic and optical products and Medical Devices, and in terms of priority areas specifically ICT, Medical Devices and Manufacturing Technology (including process technology) areas. Most important issues for companies that negatively influenced outsourcing or collaborating are a perceived complex system with no obvious access point, the strong academic culture of these centres, which make it difficult to work with in a commercial environment (timelines, professionalism etc.) and IP policies

In Section 6.4 the overseas ecosystems were assessed. Overseas centres are significantly larger in size than the SFI Research Centres and the EI/IDA Technology Centres. This gives them useful economies of scale that in Ireland can only be reached by Tyndall and Teagasc. Most overseas centres are independent from HEIs. This allows them to invest in their own capital goods, and to set up their own employment statutes. They usually have public funding horizons that are significantly longer than 5 years. This allows them to set up long-term investment plans, and offer sustainable career perspectives (and tenure tracks) to promising researchers.

7.2 Six key requirements of the future Irish research centre system

One should distinguish the following key requirements of the future Irish research centre system. Please be aware that requirement 1 to 3 follow from Technopolis' assessment of supply and industry demand for market-oriented research in Ireland. The fourth requirement follows from Technopolis' assessments of overseas market-oriented research centres. The fifth and the sixth requirement follow from expert workshops, various interviews, and feedback from Technology Ireland.

1. More middle TRL research capacity in line with needs of (Irish-based) industry. The evidence is clear and should not be ignored. Primary evidence for this need can be found in Section 5, and supportive evidence was found in sections 4.3; 4.4; 6.2. Although the Irish system is unique and requires tailor-made solutions, inspiring models might be such as the big Fraunhofer/SOC (IMEC) centres that cover a broad range of TRLs with critical mass; and the applied Competence Centres that focus on the middle and higher TRLs (validations, demonstrations, and beyond).

2. More high TRL research capacity in line with needs of (Irish-based) industry. Again, primary evidence for this need can be found in Section 5, and supportive evidence was shown in sections 4.3; 4.4; 6.2. At this point in time, industry in Ireland is not well served at these levels. Unlike Ireland, many overseas systems have RTO-like organisations that meet the requirements of industry at these levels. A commitment to higher TRL capacity must involve commitment to capital spend as well as human resources and consumables.

3. Increased offering of RTO-like research functions. The system in Ireland should allow for more short-term applied research, and contract research services (validation, testing, certification) than is offered by the current set of market-oriented research centres. Irish research centres as a group allocate most of their resources on medium and short-term problem oriented research. This was shown in Section 4.5. There is no doubt that these functions serve many companies in Ireland, as the budget figures clearly show. Yet there are clear differences with what Ireland needs in terms of research functions (which was shown in Section 4.6). Industry makes it very clear that they are in need of a broader offering of research functions than the ones currently on offer. This specifically goes for short-term applied research, and contract research services (validation, testing, certification), which are typical RTO-like research functions.

4. More operational flexibility for the market-oriented research centres in Ireland. Operational flexibility implies that centres have the mandate and the resources to invest in their own capital goods; that they can set up their own employment statutes to respond actively to changes in the labour market; and can rely on a long-term funding horizon. All components apply to most of the overseas centres that were assessed for this project. That allows them to make strategic investments that the centres in Ireland cannot make. It also allows them to strategically build a track record and a critical mass, which (as Section 6.1 showed) might take decades. This is impossible for most Irish market-oriented research centres. In addition to that, they have peer-to-peer relations with HEIs, that might be compared to what NIBRT and to some extent Tyndall have in Ireland. Centres that were analysed in The Netherlands, Denmark, and Finland, all have a clear organisational distance to HEIs that might be compared to what Teagasc has in Ireland. This operational flexibility is crucial for any centre that has the ambition to receive up to 1/3 of its funding in cash from industry and that wants to meet requirements 1 to 3.

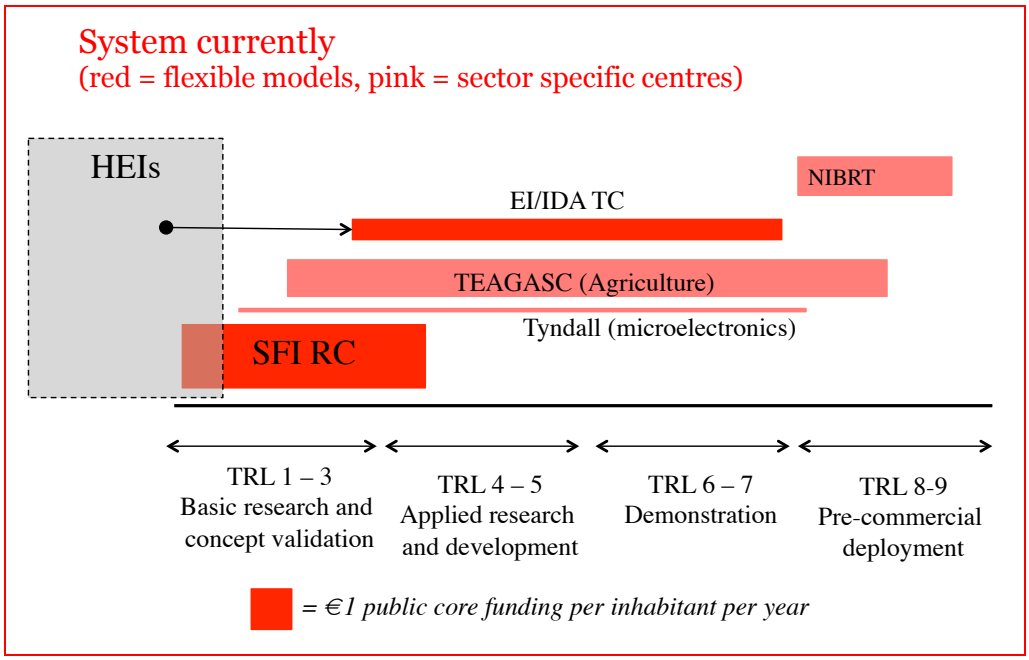
5. The need for a stronger market orientation in any new model. At the level of the agencies, their programmes, and the centres themselves, the ambition to have a market-focused research centre system is very clear. But at the level of individual researchers, there is a broad set of objectives and incentives that play in role in determining the level of market-orientation of their research. We are fully aware of the aims of the National Strategy for Higher Education and of the Higher Education System Performance Framework 2014-16. However, given the current programmatic (i.e. temporary) nature of the market-oriented research centres combined with the (very) close integration of strategic and HR policies of the centres in the general university system, a career in applied and more close-to-market research may be a risky move for ambitious researchers, compared with researcher in the organisations analysed in Chapter 6. This strong dependence on HEIs (location; staff; infrastructures, and facilities) is unique in the group of peers discussed presented in Chapter 6.

6. The need to build on existing strengths. All are aware that Ireland needs to build on the current strengths of the system. Any measure implemented should be based on existing strengths and capitalise on the substantial investments made in the Irish research centre system up to this moment.

7.3 Introduction of four measures that potentially facilitate the requirements identified

The analysis in the preceding chapters, and the key requirements of the future Irish research centre system identified in Section 7.2 lead to the conclusion that in the medium to long-term future the Irish research centre system requires several changes for it to strengthen market-focus capacity. A future Irish research system requires a research landscape that caters for the need of Irish based industry to become internationally more competitive and helps to attract foreign (RDI) investments and higher-level skills. In order to achieve this Ireland should in some domains develop a higher supply of mid- and high-level TRL activities, the provision of other types of RTO research 'services' (particularly applied contract research, demonstration capacity and research services & consultancy). This will require centres with a higher degree of operational flexibility in a long-term market-focused strategic setting than can currently be found in the Irish research landscape in specific domains, sectors, or priority areas.

Figure 39 Current market-focused research centres system in Ireland (based on 2012 ACSTI and 2015 Technopolis findings)



This selection of measures is based on the following approach:

a) A system analysis of the current Irish research centre system across TRL and research functions (see Chapter 5), based on a survey of the research centres, interviews with stakeholders and desk research;

b) An exploratory identification of a large number of 'archetype' research centre models that are based on a set of key features of research centre models, based on the results of a workshop with overseas experts on inspirations from systems and models abroad;

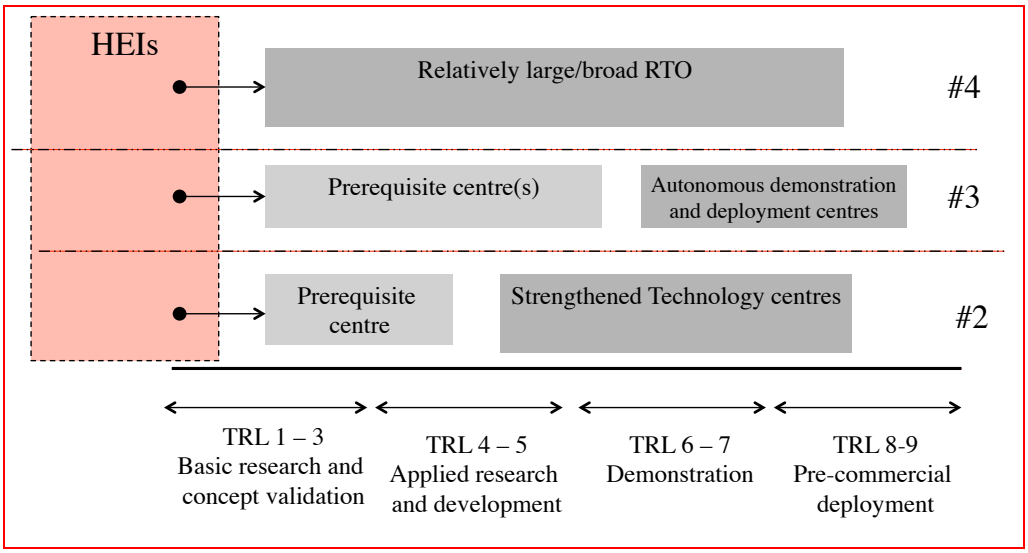
c) Prioritisation and aggregation into four high-level measures that cover the main possible approaches to address the identified future system requirements.

The selection and presentation of these high-level measures is based on 'portfolio' thinking (see Figure 40) that also emanates from the requirements of the future system.[89] In terms of the TRL scale, the key areas to be strengthened were clearly shown to be the mid-level and high-level TRLs (5+). If these areas are to be strengthened, there are three realistic and logical options:

- Introduction or strengthening of research centres active in the mid-level to high TRL research;
- Introduction of high-level TRL demonstration & deployment centres;
- Introduction or strengthening of a relatively large RTO active in TRL 2 – 7/8.

These options are not mutually exclusive, should respect and benefit from what has been built in the past years in Ireland, including the science base in the lower TRLs that is currently being conducted in the SFI Research Centres, and the universities.

Figure 40 Possible models and governance arrangements that could facilitate the four requirements identified



When making these three options operational and turning them into concrete measures, one should be aware of the following. Obviously, the Irish research centre system is not a 'blank slate' that has to be designed from scratch. A future system will, in any case, be influenced heavily by its historical path, institutions and wider context, as identified in Chapter 2. An overall key requirement for any of the high-level measures is therefore that it should be based on existing strengths and capitalise on the substantial investments made in the Irish research centre system up to this moment. Bringing these high-level measures into the context of the Irish research centre system, these three high-level possibilities have been translated into four context-specific measures (see also figure below).

[89] Like the ACSTI was in its mapping excersise (2012), we are aware that this mapping is to some extent a generalisation, and that especially the activities within the HEIs might also focus on commercial outcomes. Like the ACSTI (2012) we acknowledge that the HEI-supported centres on the far left are included in the scale simply for completeness of mapping the research centre landscape. We acknowledged that a generalisation has been made that all of these centres sit to the far left of the spectrum, and indeed it is known that at least some HEI centres carry out more user focused research activities. Moreover, it should be noted that the boundaries between the groups are notional and not rigid.

Before introducing the four measures, there is a need to stress that the reader should be aware that (1) these four measure are not mutually exclusive and that (2) the implementation of any of these measures should be incremental, which implies that Ireland should use the current system as a foundation to implement the required changes. Building new centres from scratch in Ireland is likely to be not as effective as improving what is already established in the past years, and that (3) even though most measures will ultimately strengthen the market-orientation in the higher TRLs, the need to continue to fund scientific excellence at early TRLs and encourage linkages with industry at these levels should be clear to all.

Figure 41 Introduction of four concrete measures that might facilitate the four requirements identified

Measure Nr.	Measure name	Description	§
1	**Baseline model**	No (major) institutional changes to the Irish research centre system	8.1
2	**Strengthened Technology centres**	The existing EI/IDA Technology Centre model is strengthened in terms of resources, to provide more critical mass, operational flexibility and long-term market focus in the area of mid- (and to some extent high-) level collaborative research	8.2
3	**Introduction of a demonstration & deployment centre**	A model for a high-TRL demonstration & deployment centre is introduced in the Irish research centre system.	8.3
4	**Introduction of an RTO model**	A research centre model for a broad (in terms of TRL and research functions) research and technology organisation is introduced in Ireland	8.4

Source: Technopolis Group; external experts; several workshops and interviews

It is important to emphasise that these measures (except for the baseline scenario) are *not* mutually exclusive; they could, in principle, all be pursued in parallel. It should also be clear that these do not fill the entire system. Oriented basic research should still be conducted by HEIs and by SFI centres. The universities and the IoTs should continue to feed the system with their outputs. In addition to that, centres such as ICHEC should continue their important work for the system. At the same time it is clear that these measures strengthen the market-focused aspect of the Irish research centre system in different ways and have different advantages and disadvantages. The subsequent sections will develop the high-level measures and describe potentially corresponding centre models. For each measure:

1. An overview of the new research centre system is given;
2. The key transition steps toward such a new system are proposed;
3. The primary and secondary characteristics of a corresponding research centre *model* are discussed;
4. The high-level implications for the other research centres in the Irish research centre system are analysed;
5. An assessment is made to what extent the new system and corresponding model meets the various identified requirements;
6. A summary of advantages and disadvantages of the high-level measures are given.

Note that these scenarios/measures are relatively high-level and still have a high degree of flexibility *within* them.

8. Elaboration of the four selected measures

The chapter develops the four selected models and governance arrangements identified in the previous chapter. Measure 1 (Section 8.1) sketches the consequences of maintaining the current equilibrium, which implies no (major) institutional changes will be made to the Irish research centre system. Section 8.2 discusses the implementation of Measure 2, which implies that the existing EI/IDA Technology Centre model is strengthened to provide more critical mass, operational flexibility and long-term market focus in the area of mid (and to some extent high) level collaborative research. Measure 3 implies the introduction of a high-TRL demonstration & deployment centre in the Irish research centre system. It is detailed in Section 8.3. Measure 4 (Section 8.4) sketches the introduction of a broad RTO model, which implies that a research centre model for a broad (in terms of TRL and research functions) research and technology organisation is introduced in Ireland.

It is important to note that these measures represent relatively high-level models that provide a guideline for centre characteristics. The goal of these models is to provide the basis for a high-level decision to develop a roadmap for the Irish market-oriented research centre landscape. A definitive model with full centre characteristics of these models to be used for implementation can only be the result of a detailed process based on stakeholder negotiations, consultation with legal expertise and political decisions on priorities. Since presenting level a too high of detail could unnecessarily constrain such a process, this high-level framework only serves as guidance on the most important characteristics of research centres.

8.1 Measure 1: Baseline model

8.1.1 Implications of this measure for the research centre system

This measure is visualised in the ACSTI structure in Figure 42. In the baseline measure no major institutional changes are made, and the current research centre landscape is to continue its current trajectory as sketched in Chapter 2. In Chapter 4 the expected trajectory towards a new 'equilibrium' was already presented based on the estimations of research centre directors pertaining to the development of their research portfolio in terms of TRL levels and research functions. The key differences are an increase of the SFI Research Centre volume due to the completion of the transition from the CSETs and SRCs towards this new model, which will increase the activity in the core focus of the SFI RC (TRL 1-3). The volume of more applied research (mostly TRL 4) will also increase as these centres become more mature and due to the fact that their growth targets will necessitate a further involvement (including at the decision making level). While the funding for EI/IDA Technology Centres is not expected to substantially increase in the coming years, there may be a modest shift towards slightly higher TRL levels.

The key reason why it is unlikely at this stage that SFI Research Centres will move higher up the TRL scale is the programmatic, competitive call structure of this model[90] combined with the relatively strong constraints on operational flexibility in the current model.[91] This model is well placed to provide industry-informed collaborative research of international excellence, but less suited for applied contract research and 'RTO-like' research functions.

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[90] Given that excellence in fundamental/basic research (TRL 1) is among the most important selection criterion for being awarded SFI RC funding, it is unlikely that a research centre with a strong focus on applied research would fit in the current model. See also http://www.sfi.ie/funding/funding-calls/closed-calls/sfi-research-centres-programme-2013.html.

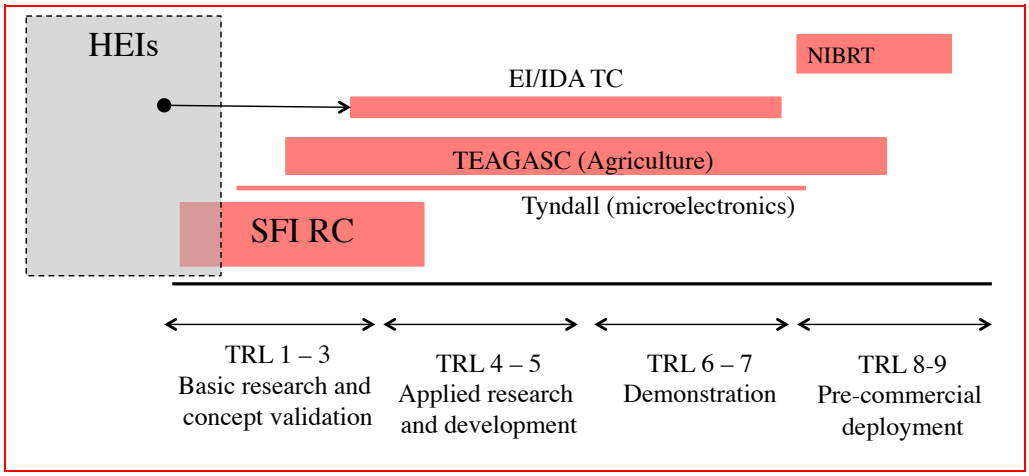
[91] We are aware of the recent investments in the Spokes Programme by SFI, and we trust that this will certainly yield effects. But the volume of investments in the Spokes is limited, the individual Spokes are still subject to constraints on operational flexibility as identified in Section 6.2.

The survey among research centre directors confirmed this argument; the large majority of them do not expect that there will be a significant shift in research functions of their centre in the near future.

Furthermore, if such a shift were to happen it would not be unequivocally a good thing: SFI research centres are designed to deliver critical research functions to industry such as long to medium-term user/problem-oriented research; and bridging academia and industry through investigator-led frontier research projects with industry participation. The demand side analysis showed that there is a substantial demand for lower TRL research (see Chapter 6), and a too large shift of the profile of the SFI Research Centres could create the risk of creating gaps in exactly those research services that also bring in, for example, ERC grants. The SFI Spokes programme is an interesting and relatively new instrument that is aimed at providing more flexibility for SFI Research Centres in engaging in opportunities arising during the runtime of a centre. Operating both under a fixed and a rolling call mechanism (requiring 50% industry co-funding), research centres can apply for joint academia (research centre)-industry projects. It is too early to investigate the impact of this new mechanism, and no evaluation is as of yet available. However, while it is likely that the Spokes programme can cover specific needs of industry by enhancing the capacity of research centre to react to evolving needs, it is unlikely this mechanism will be able to fully cover the demand for 'RTO-like' functions and higher TRL capacity due to its relatively limited size, its focus on relatively large projects (>€400k[92]) and the difficulty of combining long & medium-term collaborative research in a setting of relatively low operational flexibility.

In this measure, the other centres see relatively little change except for small developments in their portfolio sizes.

Figure 42 Visualisation of Measure 1 (Baseline model)



8.1.2 Assessment of meeting the future requirements

The table below provides an assessment of how an autonomous development of the Irish research centre system would meet the identified requirements of a future system. While some progress is to be expected in terms of mid-level TRL research, an enhanced market orientation of research centres, there remains a clear gap in providing more high-TRL research, new research functions (particularly applied contract research) and long-term sustainable and flexible research centres.

[92] SFI (2014) Frequently Asked Questions on the Stokes Programme.

		Key Assessment
Requirement 1: TRL middle	+	It is expected that the SFI Research Centres and Technology Centres over time will increase the capacity in low mid-level (SFI RC) and collaborative mid-level TRL (Technology Centres).
Requirement 2: TRL high	o	The current research centre landscape does not substantially provide the opportunity for high-level TRL research.
Requirement 3: New (RTO) research functions	o	New research functions such as applied contract research and research services are unlikely to emerge from the current research centre landscape.
Requirement 4: Operational flexibility	±	There are some promising developments in the Technology Centre model, but overall there is little expectation for a large-scale operational flexibility at the side of research centres, and the challenges with a lack of a long-term perspective for market-oriented research remain in place.
Requirement 5: Enhanced market focus	+	As the current model matures and targets of industry co-funding become stricter, it is likely to be on average more focused on the market (be it long or medium term).
Requirement 6: Building on existing strengths	+	While the current system is built on a set of strong research centres and HEI faculty groups, the system at the moment might constrain centres with long-term potential due to the programmatic centre nature and the limited operational flexibility.

Source: Technopolis

The current Irish research centre landscape has a highly programmatic nature which is a major constraint on long-term industrial engagement, development of a clear market-focused culture and strategy at the centre level, and the possibility of a career in applied research.

8.2 Measure 2: Strengthening the Technology Centres

8.2.1 Implications of this measure on the research centre system

This measure is visualised in the ACSTI structure in Figure 43. It comprises the strengthening of the technology centre model by increasing focus and critical mass and for some centres additional operational flexibility. In a recent independent evaluation of the EI/IDA Technology Centre programme, the review concluded that the programme is working well in assuring industrial participation and is viewed as industry-led. Key recommendations were: [93]

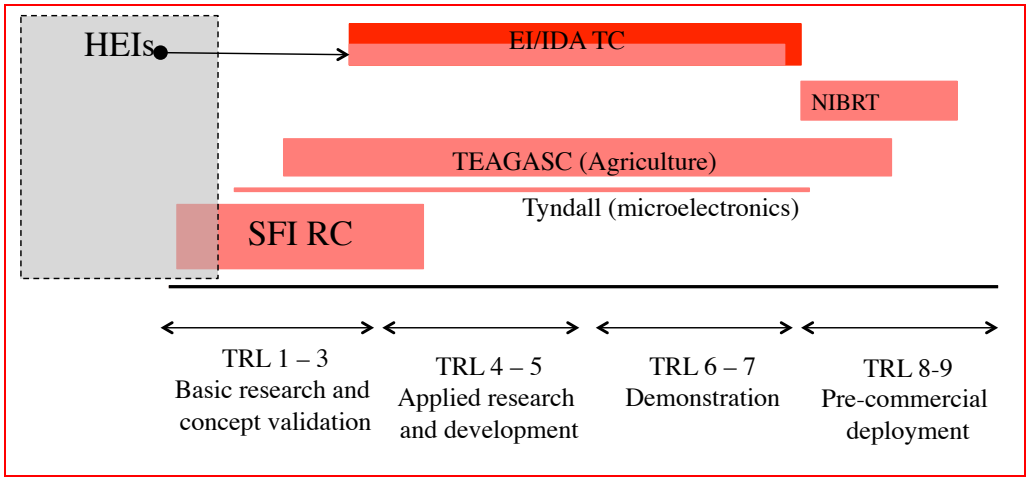
- to move to a larger critical mass for these centres;
- to consider a smaller number of EI/IDA Technology Centres;
- to consider varying governance models with higher operational flexibility for certain centres;[94] and
- to work on a succession model.

[93] Technology Centres Programme Interim Evaluation (2013) Enterprise Ireland/Frontline Evaluation, p. 7.

[94] Particularly ICMR/I2E2, which has also changed its governance arrangement in the course of 2014.

Measure 2 is based on these recommendations combined with experts' insights from overseas competence centres,[95] and data collected for the project at hand. In this model, Technology Centres will receive increased funding (resulting in larger and possibly fewer centres) in a system that is also aware of the need to continue funding the excellent work that is being done in several of the SFI Research Centres, and the crucial role that the SFI Centres have in Measure 1. As noted in the discussion of Measure 1 (Baseline Model), the supply and demand side analysis show the need for retaining activity of the SFI Research Centres in the areas of oriented basic research, medium/short term collaborative research (especially on platform technologies) in the lower and lower-middle TRL levels. In this measure, SFI Research Centres would continue to perform exactly these types of functions in the research centre landscape. Similarly, the other (sectoral) centres such as Tyndall, Teagasc do not change substantially.

Figure 43 Visualisation of Measure 2 (Strengthened Technology Centres)



8.2.2 Corresponding research centre model

The corresponding research centre model is closely based on the existing Technology Centre programme. In fact, this measure is based on an evolution of the current Technology Centre model closely in line with the recommendations of the evaluation (see above) and current developments around the ICMR centre model. The main differences are an increased size (to around 50 FTE), opportunities to gain operational flexibility in terms of HR, capital acquisition and contracting and an improved long-term perspective.

Research profile

In terms of TRLs covered, the core of activities will remain around TRLs 4-6, but its increased size and operational flexibility should allow for more short-term applied projects and contract research/consultancy, thereby also building capacity in the TRL 6 – 7 area.

The type of research functions covered will stay similar to the current technology centres, with a strong focus on medium/short-term collaborative research in technological or sectoral domains where there is a clear opportunity for a common

[95] Such as the SHOKs in Finland, DPI in the Netherlands, Bio Base Europe in The Netherlands and the Swedish Competence Centres.

research agenda. However, increasing its capacity through its increased size, these centres will also be better positioned in responding to short-term applied research, including contract research project. These centres carry out relatively little work at the basic oriented research and lower TRL levels, but rather connect (and at times cooperate) with the work of SFI Research Centres, sectoral centres and the HEI (centres). Specifically, successful SFI Research Centre technology platform programmes reaching a more applied level could apply for transition to a Technology Centre with a coalition of industry partners with a concrete ambition to take the next steps towards applied research and demonstration.

Centre size, funding model and number of centres

In order to gain more critical mass, the typical size of a strengthened Technology Centre would rise to around 50 FTE, although there would be room to have smaller or larger centres depending on the sector or technology area. This would represent roughly a two to threefold increase for the average current EI/IDA technology centre. Taking into account the need for economy and avoidance of duplication, the possible interactions with other developments in the next years (e.g. measure 4) and budget realities, the number of EI/IDA Technology centres would decrease to somewhere between 6 to 9 centres in the medium term, but with a flexibility to increase the number of centres should new technology areas emerge for which a clear industry interest is present. The composition of staff in terms of categories depends heavily on the relationship with the HEI as well as the relevant sectors and technology fields.

The funding model would evolve towards a 50-10-40[96] model, compared with a roughly 70-0-30 model now. This funding model reflects the slight adjustment that is possible due to increased income through competitive calls and contract research, but also shows that the core of the model (medium-term collaborative research which requires public co-funding) remains the most important driver. This would translate to roughly €2.5m[97] annual core public funding per centre (currently: €1m per centre).

In order to strengthen the succession model and improve the long-term horizon of this centre model while keeping flexibility in the system to respond to emerging and declining fields, a competitive open call structure with 6-year funding horizons with clear perspective on renewal could be a good system to organise the succession model. This would imply that – in the case of further success of the EI/IDA Technology Centre model – the overall budget available may need to increase in the long run.

Governance and HEI relation

Just like the current Technology Centres, these strengthened technology centres remain industry-led. Increased size and operational flexibility (where relevant) may lead to a need for more capacity in dedicated professional management with a certain degree of freedom. Managing authority (agency) could remain a joint management of Enterprise Ireland and IDA Ireland. Monitoring and evaluation of targets, which focused on industry indicators such as industry income, patents, and licences would be relatively hands-off with annual reporting.

Targets would be set by the funding agencies but in close coordination with the centre management, as the weight of various indicators should vary by type of sector or technology field (e.g. patents are less relevant in the ICT services sector).

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[96] Core:Competitive:Industry. Based on a mix of ACSTI Type 2 and Type 3 research centre model.

[97] Using a figure of €100,000 per researcher FTE.

Currently, Technology Centres are completely embedded within the framework of their host HEIs, except for the recent evolutions around ICMR. The proposed model would leave room for more operational flexibility for centres that would benefit from it but avoids a blueprint approach whereby one specific governance model is imposed on all current and future centres. Operational flexibility can of course be achieved through complete independence (e.g. ICMR), but given the current concentration of human capital and research infrastructures at HEIs it would be useful to explore a variety of operational flexibilities that gives these strengthened centres more influence or control over (among others) HR policy and research facility management (see section on transition below).

Overview of key characteristics of centre

Figure 44 Primary characteristics of Measure 2

	Primary characteristics of Measure **2**
TRLs covered	4-7 (see figure above)
Type of research	• oriented basic research (together with centre or HEI) (very small share)[98] • mid-term (collaborative) research on platform technologies (very large share) • short-term applied RDI (medium share) • Services and consultancy (small share).
Centre size (FTE)	±50 FTE research staff
Number of centres in Ireland	Eventually 6-9
Relationship with HEI	• Operational flexibility; • Possibility for a high level of autonomy • Hosted by HEI/close to relevant HEI research centre or SFI research centre.
Funding model (app.)[99]	50-10-40
Clients	• Depends heavily on by sector and type of research • Irish-owned RDI performers (medium share) • Foreign-owned Irish MNCs (high share) • Foreign clients (small share) • Irish-owned non RDI performers (small share).
Governance model (Board composition)	Member based; majority industry-led.
Total annual core funding	Eventually ±2.5m to 2.75m per year per centre, depending on maturity of predecessor (excl. capital).
Funding Horizon	Stable model, 6-year cycle, competitive allocation with clear view on possibility for renewal.

[98] Many interviewees noted the need for a better structural collaboration between EI/IDA TCs and SFI RCs, although there are various positive examples in practice.

[99] When 2 figures are given, they represent respectively income from public base funding versus and public competitive funding. When 3 figures are given, they represent respectively income from public base funding versus public competitive funding versus private funding.

Figure 45 Secondary characteristics of Measure 2

	Secondary characteristics of Measure **2**
Geographic model	Central location.
Capital model	Given limited budgets, there is a need for smart facility sharing with a research centre (e.g SFI RC).[100]
Career paths	• The Technology Centre provides a career path for relatively applied research (either on industry or on centre side). • There is relatively less room for pure fundamental research career paths.
Leadership	Independent, professional management.
KPIs (short term as well as long term)	• Complete focus on industry-related (research) outputs (100%): o Industry income o Licence revenue o Patents o FP Project revenue.
Training and knowledge transfer function	• Room for an applied RDI career path, but mostly working with more experienced researchers. • Strong focus on training and knowledge transfer between firms and research centres.

Technopolis analyses

8.2.3 Key transition steps

This model is based on an evolutionary approach that departs from the current EI/IDA Technology Centre model. The shift towards the strengthened model could be undertaken incrementally while phasing out the old model of the smaller TCs (based on criteria that were identified in the mid-term evaluation of the Technology Centres). By starting with one or two larger, more mature centres (that could evolve from existing ones) and starting the model definition process (detailed description of needs) with these two Strengthened Technology Centres in mind, combined with the current governance 'experiment' at ICMR would give insight in the next few years on the details of a sustainable strengthened TC model in Ireland. This would be in time for the phasing out of most current centres, at which time a call can be organised for current centres and new initiatives under the new model conditions. Reaching full size may take time depending on market demand of individual technology/sectoral areas.

The key high-level steps for a transition towards such a model are presented below:

- A larger Technology Centre that operates under a higher degree of operational flexibility, such as the ICMR, could be transformed into a first Strengthened Technology Centre, while a second Strengthened Technology Centre could be the result of the merger of Technology Centres in similar fields to increase critical mass
- Technology Centres could be given the bottom-up opportunity to make the transition towards the new model in terms of funding and more long-term character;
- There could be flexibility for centres to have different degrees of operational flexibility and thereby different types of relationships with HEIs;

[100] Experiences overseas show that this could lead to severe tension if industry wants access to equipment quickly for intense work and that it may slow down responsiveness of the Technology Centre.

- Improved (structural) collaboration and coordination between SFI RC and EI/IDA TC where relevant may contribute to having a sustainable model with adequate levels of 'rejuvenation' of the science base.

8.2.4 Implications for the rest of the Irish research centre system

Given the fact that these measures are relatively organic, the implications for the rest of the Irish research centre landscape are relatively limited (see table below).

Figure 46 Key implications of the introduction Measure 2

	Key implications of the introduction Measure 2
SFI Research Centres	Few to no implications except for a need to work closer together with the Technology Centres. Experiences overseas show that such cooperation can become a challenge when it comes to access to equipment (see also Footnote 100).
EI/IDA Technology Centres	The new model is based on a strengthening of the existing Technology Centres; with larger budgets and more operational flexibility.
Higher Education Institutes	Some of the 'new generation technology centres' would have slightly more operational flexibility than current Technology Centres. Whereas some of the centres might go full independence, it should be explored to devise a governance arrangement within the legal context of the HEI that gives TCs more operational flexibility.
Sector/tech specific centres) (Teagasc, Tyndall, NIBRT	Most likely limited implications for these centres, as these new centres generally would not operate in the same areas as these centres, especially not if measure 4 is implemented

8.2.5 Assessment of meeting the future requirements

The table below shows an assessment of the strengthened Technology Centre against the key requirements. This measure shows a clear strengthening of the system along various requirements, but relatively few new research functions will be made available.

		Key Assessment
Requirement 1: TRL middle	+	The strengthened competence centre model can significantly strengthen collaborative research in the middle TRL functions.
Requirement 2: TRL high	+	With access to more resources and a slightly more long-term sustainability, the centres can also offer more demonstration & deployment activities in high TRLs, but only for 'platform technologies'.
Requirement 3: New (RTO) research functions	0	Strengthened Technology Centres would deliver a strengthened base of collaborative applied research, but would most likely not be able to offer a wide range of contract research and demonstration and/or research services.
Requirement 4: Operational flexibility	+	This measure would allow for a higher degree of operational flexibility, analogous to recent developments with the ICMR and I2E2.
Requirement 5: Enhanced market focus	+	By providing (slightly) more operational flexibility, mass and long-term sustainability, there is the possibility to even further orient the centres towards a market focus.
Requirement 6: Building on existing strengths	++	This high-level measure could be achieved in a relatively fluent transition from the existing Technology Centre model.

8.2.6 Summary

The table below provides an overview of the key advantages and disadvantages of this measure.

Figure 47 Key advantages and disadvantages of Measure 2

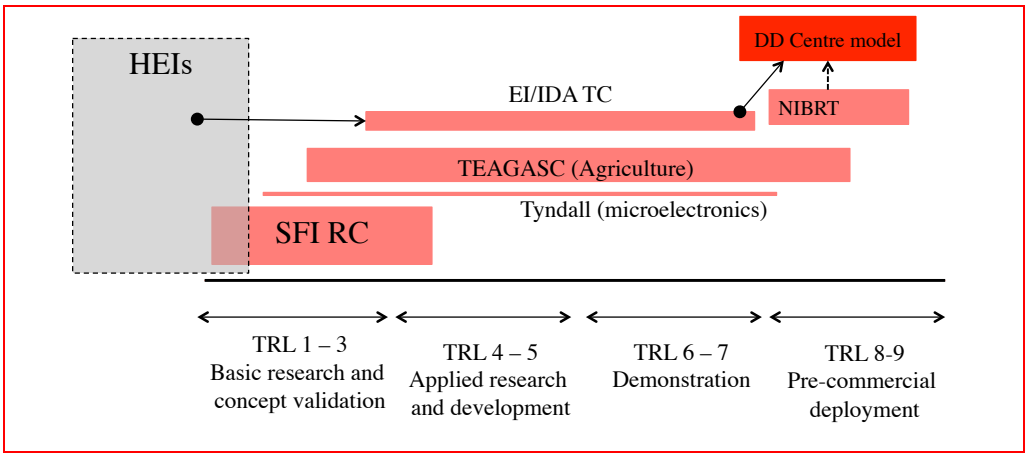
Advantages	Disadvantages
• This measure fits well within recent developments for some Technology Centres of increasing operational flexibility and increased critical mass. • Will substantially increase the availability of funding for mid-TRL collaborative research. • The increased operational flexibility and long-term security provides opportunities for a stronger development of an industrial client base. • Relatively modest additional investment required, as the measure assumes a good cooperation with SFI Research Centres, relatively low financial risk. • Potentially easier to draw in SMEs into the new type of Technology Centres, due to a slightly higher capacity to work with contract research.	• Most likely this type of model will not be able to deliver applied contract research and contract research services in any substantial volume, due to the often collaborative (and at times programmatic) nature of these centres. • There is a risk that these centres are still too small to achieve global excellence in their fields.

8.3 Measure 3: Introduction of Demonstration and Deployment Centres

8.3.1 Implications of this measure on the research centre system

This measure is visualised in the ACSTI structure in Figure 48. This measure is based on the observation that there is also a gap in the provision of very high TRL research services to industry, particularly in the area of technology validation, demonstration & deployment in an industrially relevant environment, as the current system does not feature a *model* that allows for this type of centre.[101] It would envisage the introduction of a model that is very much focused on demonstration and deployment and has very little focus on long- or medium-term research. Data received from NIBRT and the other market-oriented centres show that, in Ireland NIBRT is closest to this type of centre, and could possibly make the transition towards this future model.

Figure 48 Visualisation of Measure 3 (Demonstration & Deployment Centres)



[101] There have been incidences of individual investments in high-TRL type of centres, particularly NIBRT.

8.3.2 Corresponding research centre model

Demonstration and deployment centres could possibly be very strong in close collaboration with a relatively independent Technology Centre linked to its core activities. This idea is brought into practice in for instance Bio Base Europe in Ghent in Belgium and in Terneuzen in The Netherlands.

Research profile

The demonstration and deployment centres are clearly focused at the higher TRL levels (6-9). Due its relative 'stand-alone' approach there is relatively little room for more basic or applied research in the lower TRL areas. There could be opportunities for facility sharing and cooperation with more research oriented centres or HEI-institutes, but the key focus of this centre is at providing demonstration and deployment services for industry (testing, validation etc.). Generally SMEs[102] find it easier to make use of these types of RD&I services compared with medium or long-term (collaborative) research project, so such a centre would provide opportunities for a stronger engagement of SMEs.

Centre size, funding model and number of centres

In terms of size, the centre would roughly employ 50 FTE of 'research' staff. Due to the closeness of its activities to the market, the funding model would grow towards at least 70 per cent industry funding, 10 per cent competitive funding and 20 per cent core funding. During the definitive development of this model in the event of a political decision to pursue this, a thorough analysis of state aid complexities should be carried out, due to the closeness to market of its activities.

The new European framework for State aid has relaxed the requirements for reporting government support on demonstration activities (and not just research & development), in light of the growing interest and demand for these types of activity. Due to its relatively specific nature and capital intensity, and taking into account the fact that several larger and broader centres such as Tyndall and Teagasc, the number of centres would most likely be in the order of 1-3, although this should be mostly determined through the presence of a clear industry demand. Using these figures, the annual government grant would be in the order of €1m per centre, but it should be noted that a significant upfront investment cost could be needed if such a centre needs to be developed from scratch.

Governance and HEI relation

The D&D centre would be set up as an independent entity with no direct legal relationship with a Higher Education Institution. It would be managed by an independent professional management with strong (majority) industry representation in its board. Its managing agency would most likely be a joint management by Enterprise Ireland and IDA Ireland.

[102] This issue is less relevant for R&D intensive firms, which generally participate also at lower TRLs and through collaborative research.

Figure 49 Primary characteristics of Measure 3

	Primary characteristics of Measure 3
TRLs covered	6+ (see figure above)
Type of research	• Medium-term problem-oriented research (small share). • Validation, demonstration (medium share). • Services, consultancy, applied short-term contract research (large share).
Centre size (FTE)	±50
Number of centres in Ireland	1-3 (depending on demand side).
Relationship with HEI	• Independent. • Link to SFI Research Centres and/or EI/IDA Technology Centres for working on medium-term collaborative research.
Funding model (app.)[103]	20-10-70
Clients	• Depends heavily on by sector and type of research. • Irish-owned RDI performers (small/medium share). • Foreign-owned Irish MNCs (medium share). • Foreign clients (medium share). • Irish-owned non RDI performers (15%).
Governance model (Board composition)	Industry majority, clear industry leadership in strategy.
Total annual core funding	Eventually ±€1m per centre, depending on maturity of predecessor (excl. capital).
Funding Horizon	Stable model, e.g. 5-year cycle, competitive allocation with clear view on possibility for renewal.

Figure 50 Secondary characteristics of Measure 3

	Secondary characteristics of Measure **3**
Geographic model	Central location.
Capital model	• Strong reliance on physical infrastructure (focus on demonstration and deployment). • Need access to funding for capital. • Probably located close to partner type 2/type 3 centres.
Career paths	• Strengthens the career opportunities in development. • Independent of HEIs.
Leadership	Independent, professional management.

KPI's (short term as well as long term)	• Complete focus on industry-related commercial outputs (100%):
	  ○ Industry income
	  ○ Licence revenue
	  ○ Patents

Training and knowledge transfer function	• No focus on regular education. • Strong training component for industry staff.

[103] When 2 figures are given, they represent respectively income from public base funding versus private funding and public competitive funding. When 3 figures are given, they represent respectively income from public base funding versus private funding versus public competitive funding.

8.3.3 Key transition steps

Were the model to be established, it would be sensible to start with a pilot D&D centre that can serve as a basis for learning through experience on the best detailed characteristics for this centre model. Establishing such a pilot and having a meaningful implementation would require at least 3 to 4 years, after which a broader call could be launched.

The following key transition steps could be made to work towards the introduction of such a model:

- There would be a need to identify a pilot sector in which a demonstration and deployment centre can be started, based on clear industry demand for a particular platform technology (e.g. additive manufacturing);
- It would be advantageous to have a clear systemic view on how the centre is linked to the rest of the research centre landscape. Preferably, the centre is closely linked to one or more Technology Centres;

  NIBRT is well placed make the transition towards this model, especially given the recent investments made by IDA Ireland that have resulted in an increased research capacity in NIBRT.

8.3.4 Implications for the rest of the Irish research centre system

Given the fact that this measure comprises the introduction of a model in a TRL and research area currently not served, there are relatively few direct implications for other research centres beyond the need to introduce methods of collaboration between the new model and the existing research centres.

Figure 51 Key implications of the introduction of Measure 3

	Key implications of the introduction of Measure 3
SFI Research Centres	If the focus would be on bioprocessing (cf. Section 8.3.1) SSPC would have a clear role in Measure 3. Apart from that, research infrastructures could be possibly shared. Otherwise limited implications.
EI/IDA Technology Centres	There could be a very close synergy between the Technology Centres and the demonstration and deployment centres. If the focus would be on bioprocessing (cf. Section 8.3.1) PMTC (and possibly the Dairy manufacturing technology centre) would have a clear role in Measure 3.
Higher Education Institutes	There are most likely limited implications for the HEIs.
Technology gateways	The Technology Gateways could/should play a strong role in attracting 'customers' to the demonstration and deployment facilities.
Sector/tech specific centres) (Teagasc, Tyndall, NIBRT	NIBRT in its current form is closest to the proposed model, and could possibly shift towards the new model. Most other centres most likely have limited interaction, unless a RDI centre is set up in their particular field.

8.3.5 Assessment of meeting the future requirements

The table below provides the assessment of the demonstration and deployment centres against the various requirements identified for the future Irish research centre system. The centre provides excellent additional value in the high-TRL scales, introduces new research activities, but is less able to also strengthen mid-TRL levels.

		Key Assessment
Requirement 1: TRL middle	o	This type of centre is not heavily aimed at strengthening the middle TRLs, as it will be mostly focused on development and deployment rather than applied research. If one would decide to use NIBRT as a fundament for this measure, on should be aware that the middle TRLs will be served as well.

		Key Assessment
Requirement 2: TRL high	++	The key goal of such a centre would be to support development and deployment (i.e. very close to market) for firms.
Requirement 3: New (RTO) research functions	+	A demonstration and deployment centre is capable of delivering new research functions to the Irish research centre landscape, but is heavily focused in the area of demonstration & deployment, which also allows for research services and consultancy, but there will be less space for medium-short-term contract research.
Requirement 4: Operational flexibility	++	The proposed centre model has a very high degree of operational flexibility, despite the risk that it might struggle to attract collaboration with the constellation of Technology Centres and SFI Research Centres .
Requirement 5: Enhanced market focus	++	The centre will due to its core activities be very close to market.
Requirement 6: Building on existing strengths	o	Except for the NIBRT centre, there is relatively little physical and human capital to build this new centre on.

8.3.6 Summary

An overview of strengths and weaknesses of this model is presented in the table below. Whereas the potential added value for specific sectors or cross-sectoral platform technologies is large, this model is relatively high-risk due to a risk of isolation in the research centre landscape, state-support issues and need for strong client base. The model would work best in close conjunction with an EI/IDA Technology Centre.

Figure 52 Key advantages and disadvantages of Measure 3

Advantages/Opportunities	Disadvantages/Risks
• Potential for value-chain interaction synergies (e.g. lead equipment manufacturing pilot plants). • Especially interesting when user for platform technologies that are key inputs to various industries and sectors. • Already well-developed plans available in the manufacturing sector.[104] • High opportunities for training of industry staff.	• It is up for discussion whether this is actually a *research centre*, as even applied research will be not the core focus of its activities. • Given the closeness to market, state-aid regulations will limit the amount of funding by the government, meaning that a large share (also of capital investments) needs to be sourced from industry. Further analyses by state-aid experts is needed. • This type of centre is often relatively capital intensive, and may therefore have a higher risk of failure ('backing the wrong horse'). • It could be challenging to connect the demonstration facility to long- & medium-term research, unless there is a clear research centre in that field that can provide scientific support.

[104] IDA Ireland (2014). An assessment of industry need to establish a research centre to support Discrete Manufacturing

8.4 Measure 4: Development towards a broad RTO model

8.4.1 Implications of this measure on the research centre system

This measure is the third measure that goes beyond a baseline measure to be developed. The principal plan would be to introduce a *model*, i.e. an institutional and funding framework that provides opportunities for new and existing centres to become an Irish research and technology organisation. In its essence, this model is a relatively large centre (people and infrastructure) with a certain critical mass that has a strong focus on serving industry needs through contract (and possibly collaborative) research with a relatively stable and secure core funding that allows for the provision of long- and medium-term user/problem-oriented research as well, with consultancy services and testing services.[105] Its core focus is pre-competitive applied RDI.[106] This research centre model has a relatively broad TRL span except for the extremes (e.g. limited pure basic research). Note that such a policy-level *model* can still allow for a large variation in the implementation of individual centres of aspects governances, KPIs, IP policies etc., as these tend to be very technology/sector-specific. One could also say that ICMR might qualify for this as it has some of the mass needed, a substantial client base, and as it has recently transitioned to a quasi 'RO' model for governance and state aid reasons.

The figures below provide an overview of the new research centre system. One of the advantages of this model is that it also provides a potential rationalisation & simplification of the current system, as various existing sector-specific centres could potentially fit under this model. Tyndall and Teagasc,[107] in terms of activities, operational flexibility and long-term character already closely match this model and could potentially be accommodated under it. NIBRT has a track record in the higher TRL level activities the high-level TRL activities, and could – if successful in expanding its research base – potentially also fit this model. Furthermore rationalisation of NIBRT with the PMTC Technology Centre and stronger/formalised links with the SSPC Research Centre might strengthen this further. Finally, a core advantage of this model would be the possibility to substantially increase the dynamism in the research centre system by offering a long-term perspective to successful SFI research centres that have attracted a strong (potential) client base and are slowly becoming 'too applied' for renewed SFI funding.

By offering a long-term perspective to successful SFI research centres that have attracted a strong (potential) client base and are slowly becoming 'too applied' for renewed SFI funding (and transforming these organisations into RTOs), SFI funding is freed up for investment in 'next-generation' technologies and fields, as was stated by SFI.

[105] EARTO (2010) The impact of European RTOs.

[106] Arnold et al. (2012) Research Centres in Ireland: Funding Models, oversight and vision of a future research centre landscape.

[107] Teagasc has a different legal standing and also has various other activities besides research, the reasoning here is based on an analysis of their de-facto research activities.

Figure 53 Visualisation of Measure 4 (Broad Research & Technology Organisation in stage #1)

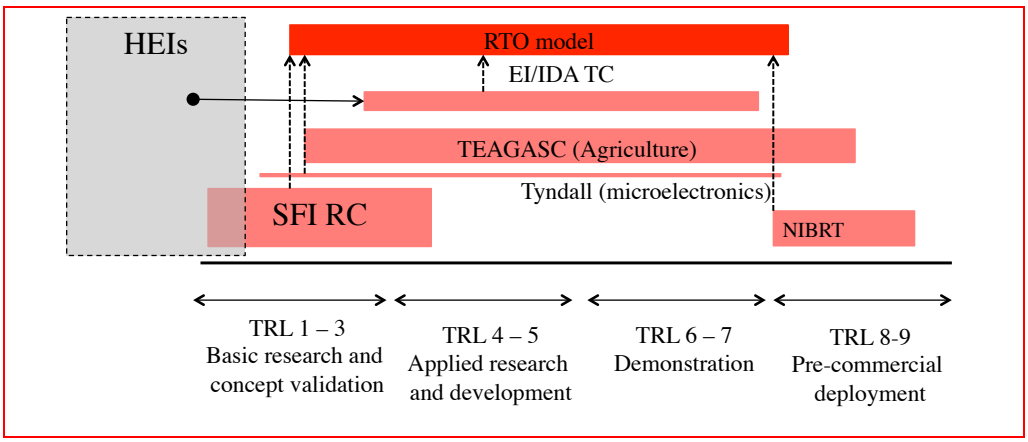
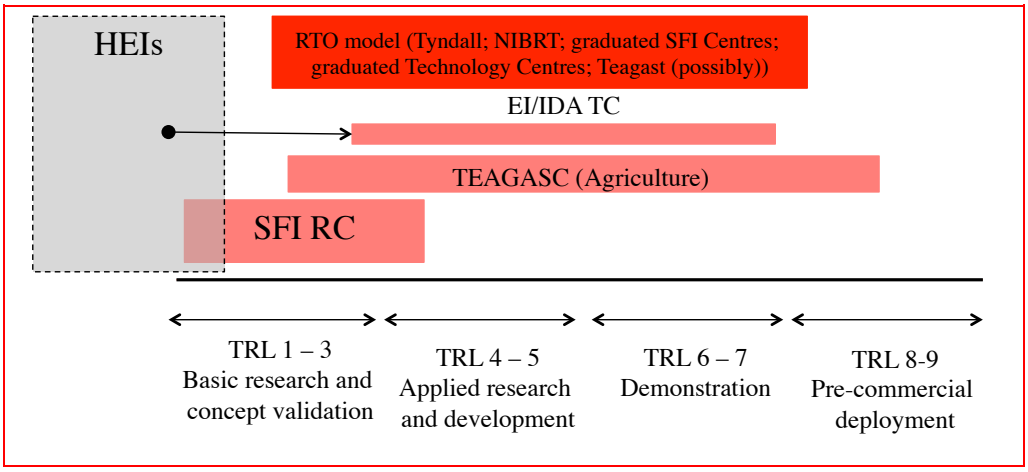


Figure 54 Visualisation of Measure 4 (Broad Research & Technology Organisation in stage #2)



8.4.2 Corresponding research centre model

Research profile

This model, which could be classified as an RTO, would focus its research activities on conducting applied R&D, technology and knowledge development covering the TRL areas of 2-8 and focusing on medium-term (collaborative) R&D, short-term applied research and contract research services & consultancy. Operating with a business-like culture in a relatively independent setting with operational flexibility, these centres are designed in terms of structure and incentives to continuously respond (pro-actively and reactively) to industry demand. Through their activities on contract research services, such as validation, testing, piloting etc. RTOs are also active at high TRL areas such as TRL 7 and 8. Generally SMEs[108] find it easier to make use of these type of RD&I services compared with medium or long-term (collaborative) research

[108] This issue is less relevant for R&D intensive firms, which generally participate also at lower TRLs and through collaborative research.

project, so such a centre would provide opportunities for a stronger engagement of SMEs.

Specific attention should be paid to the balance of collaborative and contract research, of which the profile of RTOs is very domain/technology-specific. Almost all RTOs combine both types of research as general competences on platform technologies are built in collaborative research which spill-over in the medium term to competences in contract research (this needs a balanced IP strategy to function properly).[109] In general, contract research can be more flexible in accommodating very concrete, close-to-market industry needs as there is no need to find a joint pre-competitive research agenda such as in a collaborative R&D project. Good access to contract research (which was shown to be one of the areas least served in Ireland) has also shown to be important in strengthening companies' competitiveness, as it prevents focusing exclusively on projects that are acceptable to a large group of companies (and therefore at times less risky).[110]

Centre size, funding model and number of centres

The envisaged RTO model needs to have a high critical mass in order to be successful. RTOs benefit from scale advantages, including organisational capacity (see also further below), the ability to respond flexibly to rising industry demand, and the capacity to build competitive excellent areas that can draw in international industry funding. Furthermore, while RTOs need a clear technology or sectoral focus and strategy, they also need a certain size to be able to manage a portfolio of several (related) areas of excellence (to reduce risk of sudden shifts in demand). The international comparator centres have staff sizes of between 200 (TNO) and 3000 (IMEC) researcher FTE. Given the size of the Irish R&D system and the relatively short tradition of Ireland in attracting RTO-like function-related industry funding, a realistic short to medium term estimate of the centre size would therefore be in the lower bound of this range at ±250 – 500 researcher FTE, depending on the current maturity of predecessor centres. However, in the long run successful centres could definitely grow beyond these figures, especially if they manage to attract international industry funding.

Note also that these centres – due to their size – almost always need to be European or global in their ambition. International public competitive funding (especially Horizon 2020 and successor programmes) will be a key part of research strategy, but applied contract research requires a substantial client base which will most likely go beyond Ireland. As such, these centres will only exist in areas where Ireland has (or will have) strong international research competitiveness.

RTOs typically use a target of a ratio of 1:1:1 in terms of core funding, competitive funding and industry funding.[111] [112] While some very successful centres in terms of acquiring industry funding have lower core grant shares (such as Imec at ±20%), the typical model of equal shares would be relatively consistent with targets elsewhere in Europe (though a ramp-up period would be required). This translates roughly €15m per RTO core funding (operational costs)[113]) per RTO per year.

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[109] TNO (2005) Benchmarking contract research organisations.

[110] Porter, M. (2008). On Competition. Harvard Business School Press.

[111] It is very important to stress that private/industry income can also come from non-commercial organisations, including government departements. Various RTOs (e.g. TNO in the Netherlands, VITO in Flanders) have specific (long-term) government contracts for research and consultancy services, especially in areas of testing (agriculture, food, environment etc.) or defense research.

[112] ACSTI (2014) Sustainability of research centres.

[113] These estimates, and similar estimates elsewhere, assume that there is another policy instrument to support research infrastructure investments, such as the PRTLI schemes.

The core funding should be across relatively long-term periods of 5 years, as evaluation of RTOs have showed that a long-term perspective is important for strategic focus and operational flexibility and to avoid a focus on governance cycles.[114] In addition a tacit or even explicit understanding that an RTO intended to be 'there to stay' strengthens the long-term focus that was identified as a major requirement for a new research centre model for Ireland. It should be noted that this also means that significant volume of industry co-funding and demand for contract research needs to be available for such a centre to have a chance of success. This effectively means that RTOs can only be established in areas with proven concrete and consistent industry demand.

It is interesting to note that RTOs generally have relatively high but very focused overhead costs (between 20%-40%). Larger, relatively independent research organisations can afford to invest not just in R&D-support staff (such as lab technicians) professional IP officers, and a legal department, but also in professional business development teams.[115]. Due to the latter, RTOs are generally very successful in attracting international competitive funding such as the Horizon 2020 programme. FP7 and FP6 league table in terms of funding acquired are filled with RTO(-like) organisations.[116] An evaluation of IMEC in Flanders has shown that the government can play an important support role in accessing large European initiatives (JTIs).[117] Irish RTOs could provide the organisational capacity in their respective fields to exploit their position to also boost the participation of Irish companies (including SMEs) and HEIs, as they are more likely to have the capacity to serve as consortium leader.

Governance and HEI relation

Whereas SFI Research Centres could be described as 'academically led-industry inspired' and EI/IDA technology centres as 'industry led-academically supported', an RTO with operational flexibility that avoids a programmatic nature (and is as such indeed an *organisation*) could best be described as 'professionally led, industry oriented, and academically inspired).

A clear hallmark of RTOs is that they are able to decide on their own strategy independent of academia and industry – be it by definition in very close coordination with both HEIs and industry clients/partners. There is a need to develop a distinct industry oriented organisational culture that is reflected in the incentives and career opportunities for individual researchers. The long-term horizon and critical mass that an RTO can offer could provide a very strong boost in creating a clear industrial/applied R&D research career path, which strongly complements and strengthens Ireland's human capital development efforts.

Over time, as experienced industrial researchers move in and out of industry, the RTO and academia, this could significantly contribute in creating a stronger and competitive research & innovation ecosystem in Ireland.

Typical governance arrangements include a management board (appointed directly by the line ministry) that has relative freedom to implement the strategy agreed during the 5-year cycle review, reporting annually on the progress of its KPIs. The level of government intervention in terms of monitoring is relatively low and is focused

[114] VTU (2009) A step beyond: international evaluation of the GTS Institute System in Denmark.

[115] TNO (2005) Benchmarking contract research organisations.

[116] See for instance: Technopolis (2014) Evaluation of the FP6/7 Energy projects.

[117] Boekholt, P. et al. (2011) Meta-evaluatie van Imec: managementsamenvatting.

around a cyclical evaluation (after four years, to provide input for the renegotiations) based on agreed targets for KPIs and a more overall evaluation of the RTO.

Based on the evaluation, the government and the RTO would agree on new targets and funding levels in the management agreement for the next funding cycle. It is not immediately obvious which current agency or department should administer the RTO model. Given the scale and the interaction with various other policy instruments, a steering committee comprising DJEI, HEA, SFI, EI and IDA could be jointly responsible for monitoring and evaluation, while the operational work and day-to-day contact point could be at the DJEI. Governance arrangements such as these should be further explored during the pilot phase.

Typical KPIs include a mix of industry-oriented (70%) and academic (30%) outputs and impacts that should reflect the strategy of the specific RTO. KPIs could include industry income, patents, licences, turnover from spin-offs (industry-oriented) and publications & citations (academic outputs), but the relative weight within categories varies between technology areas and sectors. Performance management and monitoring of these KPIs should be implemented at every level of the organisation in order to stimulate researchers to align their work with that of their organisation's strategy.

An important key feature of this approach would be a strong relationship with HEIs combined with a strong operational flexibility. In order to pursue a long-term, industry-focused research centre with a market-focused *culture*, these centres require (at least some) independence in strategic management, HR and capital acquisition. However, there is close collaboration with the HEIs in low-level TRL research, training of MSc candidates, PhD candidates, higher awards in engineering, sharing of facilities and long-term strategy. This clear relationship with the HEIs should come with a formal independence, which is key for the organisation to be able to build intensive collaboration with industry in the higher TRLs. Experiences from overseas[118] show that this *clarity of mission* and *clear division of roles* can result in a mutually beneficial research ecosystem where both excellence in basic research as well as applied (contract or collaborative) research has a dedicated space. Several countries have good experiences in working with joint fellowships for senior researchers (including the centre director) at HEIs,[119] and several RTOs abroad show that they can serve as an important source of access to training facilities for PhDs and post-doctoral researchers.[120]

Physical presence close to the main relevant HEIs is important to make optimal use of the interaction between HEI and RTO (e.g. Fraunhofer or IMEC models follow this pattern).

However, it should be acknowledged that there is a clear risk of too much detachment between the RTO and the HEI system, also shown by evaluations of comparators.[121] Given the continued strategic decision to focus research infrastructure and human capital within HEIs in Ireland (with some exceptions), this specific aspect should be given even more attention than usual during the development of the detailed characteristics of the model during a pilot phase. If done well, in close coordination with clear *clarity of roles* on all sides, an evolved situation such as presented here can be of strong mutual benefit.

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[118] As discussed during the expert workshop.

[119] TNO (2005) Benchmarking contract research organisations.

[120] VTU (2009) A step beyond: international evaluation of the GTS Institute System in Denmark.

[121] VTU (2009) A step beyond: international evaluation of the GTS Institute System in Denmark.

Overview of characteristics

A summarised overview of the main characteristics is presented in the table below.

Figure 55 Primary characteristics of Measure 4

	Primary characteristics of Measure 4
TRLs covered	2-7/8 (see figures above)
Type of research	• low share % basic oriented (together with HEI) • medium share% long-term user-oriented (e.g. FP) Depending on sector/industry demand • medium share% mid (collaborative) research on platform technologies • low/medium share % short-term contract research. OR [122] • high% medium & short-term contract RDI • low% Services and consultancy.
Centre size (FTE)	±250-500
Number of centres in Ireland	Eventually 2 -4 , depending on whether Tyndall, Teagasc or NIBRT would transition to this scheme
Relationship with HEI	• Operational flexibility; High level of autonomy • Active collaboration with by (one or two) HEIs but distinct organisation ('across the road') • Joint appointments of PIs, and MScs, PhDs awarded by partner institutions • Very close interaction with HEI-based research centre & faculty in same technology field • Strong academic link with host HEI: professorships, joint PhDs, publication record.
Funding model (app.)[123]	33-33-33
Clients	• Depends heavily on by sector and type of research • Irish-owned RDI performers (low-medium share) • Foreign-owned Irish MNCs (medium share) • Foreign clients (medium share) • Irish-owned non RDI performers (very low share).
Governance model (Board composition)	Professional, independent board composition with a mix of industry and academia.
Total annual core funding	Eventually ±15m per centre, depending on maturity of predecessor.[124]
Funding Horizon	Stable but flexible model. For each centre a long-term horizon, five-year external (peer) review. This review might result in shifts in strategy.

[122] Whether there is room for collaborative research depends to a large degree on the specific technological field and industry composition. IMEC (Flanders) works with significant levels of collaborative research thanks to a strong industrial roadmap on the development of future platform technologies. Various other RTOs (e.g. VITO, Fraunhofer, TNO) are more focused on contract research.

[123] When 2 figures are given, they represent respectively incomes from public base funding versus private funding and public competitive funding. When 3 figures are given, they represent respectively incomes from public base funding versus private funding versus public competitive funding.

[124] Initially higher core funding of a smaller but increasing size may be required.

Figure 56 Secondary characteristics of Measure 4

	Secondary characteristics of Measure 4
Geographic model	Central location, possibly later with spokes.[125]
Capital model	• There is a need for a high degree of operational flexibility regarding capital acquisition. Research infrastructures can be shared with HEI but on a clearly defined basis on equal footing. • There is also the possibility to have shared ownership with industry. • Equipment vendors may make equipment available to a suitably ambitious centre if they see an opportunity to validate and demonstrate its utility to potential end user in industry)
Career paths	• RTO offers a long-term industrial (applied) research path, as well as a small number of professional research management career tracks. • A small share of researchers may have joint faculty/RTO appointments.
Leadership	Independent, professional management. High-level management (PI levels) can/must have HEI professorship (with limited obligations).
KPI's (short term as well as long term)	• Clear focus on industry-related outputs (70%): o Income from industry o Licence revenue o Patents o Horizon 2020 Project revenue o Spin-off turnover • Academic outputs (30%)[126] o Publications. o Citations
Training and knowledge transfer function	• Strong focus on Engineering, MScEng, MSc PhD-level training (together with HEI) , with relatively high share of PhDs moving to industry after graduation. • When the centre is (mainly) engaged in collaborative research, there is a substantial training component for (resident) company staff. • Apprenticeship training and upskilling for existing employees on latest technology (can serve as a revenue stream as per NIBRT).

8.4.3 Key transition steps

It is quite clear that the evolution towards the introduction of an RTO-model is a complex process during which the model at the policy level but also the RTO-specific implementation at the individual RTO level needs to be developed in full detail. As mentioned in the introduction to this chapter, this entails a process of political priority setting, stakeholder negotiation and accessing of various specific expertise (including legal, IP, HR, tax etc.). A sensible choice could be to commence with a pilot RTO during which these steps can be taken and subsequently evaluated to inform further rounds. A choice for a relatively mature 'proto-RTO' (see Chapter 9) could speed up this process as such a centre can much faster establish itself under the new model.

[125] In this case spokes refers to decentral small units attached to research groups/industry clusters in another location.

[126] Based on a mix of Type 2 and Type 3 ACSTI criteria.

In order to arrive at this new model, the following high-level transition steps would be required:

- Separation between HEI-activities and centre activities (with clear distinction in clarity of mission) with strong mutual dependence/interaction in the scientific areas (part-time professorships; joint publications etc.);
- Raising awareness for a higher degree of operational flexibility (in terms of HR, capital acquisitions, strategy and IP) to these centres, establishment of a legal entity;
- Giving the centre a long-term, semi-permanent remit with the main target to serve industry needs and a specific funding target (with 5 year evaluations yet longer funding horizons as explained in the next chapter);
- SFI Research Centres with a strong enough industry base and additional Spokes capacity could be given more operational flexibility and long-term perspective, possibly merged with tech centres in the specific sectoral or technological fields.

8.4.4 Implications for the rest of the Irish research centre system

Naturally, introducing such an RTO model has substantial implications for the other research centres in the system. An overview of implications is presented in the table below.

Figure 57 Implications of the introduction Measure 4

	Implications of the introduction Measure 4
SFI Research Centres	The current generation of SFI research centres can (in certain cases) be considered a 'proto-RTO'. RTOs could be developed from successful SFI RCs that have a strong industry base and a long-term research agenda, and slowly but surely shift to a more applied focus in a setting with more operational flexibility and a clear division of roles between the centre and the host HEI (e.g. creation of separate HEI institute in that specific field). This 'graduation' of centres could free up resources for new SFI RCs that can build a (collaborative) research base in upcoming sectors/technology. SSPC may be closest in this regard and if graduating to an RTOP could be done in a way to merge with NIBRT and PMTC and thereby rationalise overall research centre landscape. Co-existence of an SFI research centre with this new type of RTO in the same technology/sectoral field seems therefore unlikely.
EI/IDA Technology Centres	The EI/IDA Technology Centres (or expanded versions as in Measure 2) could complement the RTO in sectors that have a relatively lower industry demand or which are more exclusively focused on Irish resident firms. For example: PMTC is an EI/IDA Technology Centre that could be merged into a NIBRT RTO. CCAN was an EI/IDA Technology Centre that had significant overlap with Tyndall yet it is in the process of being sunsetted. Given the concentration of critical mass in such an RTO, it would not seem evident that there would be Technology Centres in the same field.
Higher Education Institutes	There will be a close relationship between the RTO and the host HEI(s), see also general description above. However, the extent of operational flexibility will be much larger compared with the current SFI Research centres. Certain facilities could be shared, but there is a clear division of roles between the RTO and the HEI. In the medium to long run a clear mutually beneficial research ecosystem could strengthen the HEIs significantly.
Technology gateways	RTOs could also be set up around (among others) a Technical University with a strong (applied) research faculty. The Technology Centres could position themselves to bring in clients (particularly SMEs) for collaborative and contract research.
Sector/tech specific centres) (Teagasc, Tyndall, NIBRT	Tyndall already closely fits the RTO model described above, and could shift relatively easily into this new research centre model. Teagasc has also characteristics of an RTO, although it also performs various other services besides research. Should NIBRT strengthen its research base substantially, it could also – in time – fit under the model.

8.4.5 Assessment of meeting the future requirements

The characteristics of the new research centre model in its future system have been assessed against the requirements that were identified for a strengthened market-focused Irish research centre system. The result of this assessment is presented below. In sum, this model – if successful – would clearly meet most of the requirement for a future market-focused research centre model, and would most likely be able to significantly strengthen the capability of the system support market-focused research. A more comprehensive overview of advantages and disadvantages is given in the next section.

		Key Assessment
Requirement 1: TRL middle	+++	Introducing this model would indeed increase the middle TRL (applied research), but only in a relatively small number fields with a strong industry base.
Requirement 2: TRL high	++	Introducing this model would indeed increase the high level TRL (validation, demonstration & deployment), but only in a relatively small number fields with a strong industry base.
Requirement 3: New (RTO) research functions	++	Applied research, contract research and research services would be significantly strengthened.
Requirement 4: Operational flexibility	+	This model would increase the operational flexibility in the system.
Requirement 5: Enhanced market focus	++	Through its KPIs (short term as well as long term), mission, dependence on industry funding and significantly increased operational flexibility.
Requirement 6: Building on existing strengths	+	The model would require quite significant changes from the current system, but does build on existing strengths.

8.4.6 Summary

Based on interviews with Irish stakeholders, literature review and expert assessment, the key advantages and opportunities, as well as the disadvantages and risks for this approach have been summarised below.

Figure 58 Key advantages and disadvantages of Measure 4

Advantages/Opportunities	Disadvantages/Risks
• This model would offer exactly the research functions currently in 'short supply': applied (contract) research and research services. • Can function as a strong bridge between excellent long & medium term research and industry contract research. • Due to its critical mass, there is a higher chance that these will be able to deliver applied research of global excellence (and thus attracting foreign funding). • Provides opportunities to rationalise/simplify the current research centre system by providing a model for Tyndall and possibly Teagasc. • Provides opportunities for continuation/transformation of successful SFI research centres that have become 'too close to market' for continued SFI funding; thereby freeing up funding for new SFI centres new	• These relatively large RTOs require a relatively long time to become established with a strong industrial client base. • This model organisation would rely significantly on mostly large domestic and foreign industry funding; there is a risk the Irish system is too small/volatile for such a continued base. • Given its large size and required industry base, only a small number of these organisations could be supported in the Irish research centre system, thereby most likely not having a full sectoral/technological coverage. • There is a clear risk of competition for resources (including staff) with HEIs. • Usually more difficult to provide services to (non-RDI performing) SMEs.

Advantages/Opportunities	Disadvantages/Risks
upcoming areas.[127]	

8.5 Measure summary table

The table below provides an overview of the various measures and their respective characteristics. It is clear that there is no single model that addresses all requirements perfectly. Introducing an RTO is complex and possibly costly (in new areas), but could serve as a comprehensive approach for certain technologies and sectors where it can result in a better balanced research services portfolio in the Irish research centre system. Strengthening the Technology Centres could lead to worthwhile improvements without revolutionising the system, whereas the introduction of a demonstration and deployment centre can be high risk due to a lower adaptive capacity.

	Measure 1 (Baseline Model)	Measure 2(Strengthened TC)	Measure 3 (D&D centre)	Measure 4 (RTO model)
Requirement 1: TRL middle	+	+	0	+++
Requirement 2: TRL high	0	+	++	++
Requirement 3: New (RTO) research functions	0	0	+	++
Requirement 4: Operational flexibility	±	+	++	+
Requirement 5: Enhanced market focus	+	+	++	++
Requirement 6: Building on existing strengths	+	++	0	+
Sector coverage of centre model	-	High	Low - Medium	Low
Risk of failure	Low	Low	High	Medium
Transition	NA	Medium complexity	Low complexity	High complexity
System rationalisation and simplification	None	High	Medium	Low
Additional state investment costs	Low	High	Medium	Medium
Establishment horizon	NA	3-7 years	3-5 years	5-10 years

The next chapter discussed the Roadmap for the development of a competitive market-focused research centre landscape in Ireland to 2025 and beyond. The Roadmap follows the structure that was agreed with DJEI in the Project Plan.

[127] See also 'Impact of European RTOs' (2012) EARTO. For a specific example, see also the evaluation of IMEC (2011) cited before.

9. Roadmap for the development of a competitive market-focused research centre landscape in Ireland

9.1 The measures that Ireland needs and that would fill the main gaps

Based on the analyses of data received from almost all Irish market-oriented research centres; thirteen (group) interviews with 18 key stakeholders from relevant agencies, employers organisations, research centres, and industry; our Expert Workshop; our two Stakeholder Consultation Workshops that validated our findings; our various qualitative sources; our analyses of ABSEI; Eurostat and OECD data, as well as a survey filled out by a large group of RDI intensive companies in Ireland, the choice for a Measure 3 (Introduction of a broad RTO model in Ireland), added with certain elements of Measure 2 (Strengthening of the Technology Centres) seems evident whist still ensuring that SFI Research Centres continue on their existing trajectory.

Requirement 1 (strengthening the middle TRLs) is only met by Measure 1 (maintenance of the Baseline Model), Measure 2 (Strengthening the Technology Centres), and Measure 4 (Development towards a broad RTO model). Only these measures significantly serve the need for an increased activity at both the middle TRLs. Measure 4 will have most impact as was shown in Chapter 8.

Requirement 2 (strengthening the high TRLs) is only met by Measure 2 (Strengthening the Technology Centres), Measure 3 (introduction of Demonstration and Deployment Centres) and Measure 4 (Development towards a broad RTO model). Only these measures significantly serve the need for an increased activity at both the high TRLs. Measures 3 and 4 are likely to have to have most impact as was shown in in Chapter 8.

Requirement 3 (new research functions) is only met by Measure 3 (introduction of Demonstration and Deployment Centres) and Measure 4 (Development towards a broad RTO model). Only these measures significantly serve the need for an increased activity at the A3 and A4 research functions. Measure 3 will have most impact as was shown in Chapter 8**.**

Requirement 4 (Operational flexibility) is primarily met by Measure 2 (Strengthening the Technology Centres), Measure 3 (introduction of Demonstration and Deployment Centres) and Measure 4 (Development towards a broad RTO model). Only these measures significantly serve the operational flexibility in the future centre landscape. Measures 3 and 4 will have most impact as was shown in Chapter 8.

Requirement 5 (Enhanced market focus) can be met by all measures, including the baseline model. However, most impact in terms of market focus should be expected from Measure 3 (introduction of Demonstration and Deployment Centres) and Measure 4 (Development towards a broad RTO model).

Requirement 6 (Building on existing strengths) can be met by all measures, except Measure 3 (introduction of Demonstration and Deployment Centres). However, most impact in terms of market focus should be expected from Measure 2 (Strengthening the Technology Centres).

9.1.1 Conclusions on measure suitability

Using the conclusions above in terms of meeting the identified requirements and taking into account the aspects of risks, transition complexity, system rationalisation and simplification, additional investment costs and an establishment horizon, we arrive at the following conclusions:

- All three change scenarios for Ireland present opportunities in addressing parts of the requirements of the future Irish research centre system. The models are not mutually exclusive but complementary, although care should be taken when centres operate in the same technology or sectoral area.

- A tailored version of the broad RTO model (Measure 4), with specific focus on integration with the current system and reduced transition complexity scores best on being able to provide more of the applied type of RDI activities companies need, and could improve operational flexibility and enhance market focus.
- A modified version of the strengthened Technology Centres model (Measure 2), with attention to focusing on improving the current centres through a broader mix of governance options allowing for greater operational flexibility and improved focus and mass, could complement the broad RTO model without a need for high transitional costs.
- The demonstration and deployment centre (Measure 3) in isolation, while bringing in the high TRL areas and new research functions seems at the moment high-risk and relatively disconnected from the current research centre system. It would operate best if closely connected to an (applied) RTO or Technology centre that already has a strong commercial track record. Elements of the D&D centre could be covered in an RTO setting, or the model could be considered in due course when the Irish system is more 'ready'.

The Roadmap should therefore work towards a combined version of evolution towards an adapted broad RTO model and a strengthening of the Technology Centres.

9.2 The added value of combining a broad RTO model with strengthening the Technology Centres

The combination of both a development towards a broad RTO model, and a strengthening of the Technology Centres is an interesting option for Ireland.

9.2.1 Evolution towards a broad RTO model

The implementation of a broad RTO model would result in a funding framework that provides opportunities for new and existing centres (for example SFI Research Centres, or EI/IDA Technology Centres, or Teagasc, Tyndall or NIBRT) to become an Irish RTO. Its ultimate core focus would be pre-competitive applied RDI, including contract research.[128] This research centre model has a relatively broad TRL span except for the extremes (e.g. limited pure basic research). It would however be demarcated in terms of sectors or technologies, and be therefore primarily available to a specific part of Irish industry.

One of main the advantages of a broad RTO model is that – apart from the fact that it meets the requirements identified – it provides a potential rationalisation & simplification of the current system, as various existing sector-specific centres could potentially fit under this model. Tyndall and Teagasc,[129] in terms of activities, operational flexibility and long-term character already closely match this model and could potentially be accommodated under it. NIBRT has a track record in the higher TRL level activities, and could – if successful – potentially also fit this model if it would find connection to lower-middle TRL research. Further rationalisation of NIBRT with the PMTC Technology Centre and stronger/formalised links with the SSPC Research Centre might strengthen this further. Finally, a core advantage would be the opportunity to substantially increase the dynamism in the research centre system by offering a long-term perspective to successful SFI research centres that have attracted a strong (potential) client base and are slowly becoming 'too applied' for renewed SFI funding.

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[128] Arnold et al. (2012) Research Centres in Ireland: Funding Models, oversight and vision of a future research centre landscape.

[129] Teagasc has a different legal standing and also has various other activities besides research; the reasoning here is based on an analysis of its de-facto research activities.

With this approach, transforming these organisations into RTOs, SFI funding is freed up for investment in 'next-generation' technologies and fields. Given our industry demand survey showed that companies are also indicating that there is a continued need for long-term oriented basic research, this could be an excellent mechanism for ensuring that scientific excellence is sustainably generated and feed into the higher TRLs of the Irish system.

Based on our needs assessments and on the interviews and workshop, one can say that in the medium term there could be enough demand for at least two to four RTO-like organisations. Each of these organisations could ultimately consist of 250 to 500 researchers. The research would focus mostly on the middle and high TRL range, but also be active in lower TRL areas. In this research, the broad RTOs would have great operational flexibility and have more autonomy from the current HEIs. However, the HEIs and RTOs in a specific domain would explicitly try to strengthen each other. The HEIs can facilitate MSc and PhD education, as well as professorships, while the broad RTOs can facilitate industry collaboration, and increased Horizon 2020 participation. There can be sharing of facilities, but with a clear access policy that in general prioritises (contract) research activities.

The annual core funding would have to be about €15m. The funding horizon would be long-term, based on a five-year external review process.

Ultimately there would need to be a high degree of operational flexibility regarding capital acquisition. Research infrastructures can be shared with HEIs under clear user agreements. Shared ownership with industry should be encouraged, as is done at overseas RTOs. The broad RTOs that result from this measure should offer long-term industrial (applied) research career paths, as well as a small number of professional research management career tracks. Top management should be independent and professional, as is currently the case in several market-oriented centres in Ireland. The KPIs should primarily be oriented at increasing industry collaboration. As a consequence they would include, for example, income from industry; licence revenues; patents; Horizon 2020 project revenues. Publications should be less important as a KPI.

A small share of researchers may have joint faculty/RTO appointments. Any result of this measure should have a strong focus on education and training, more specifically on Engineering, MScEng, MSc, and PhD-level training. All this should be done in close collaboration and co-ordination with the relevant HEIs, who are responsible for higher education. The Fraunhofer Institutes could serve as an example for this aspect. The RTOs should aim for a relatively high share of PhD moving to industry after graduation. Apprenticeship training and upskilling for existing employees will serve as important revenue streams.[130]

It is important to be aware that any result of this measure would need to be European or global in its ambition. International public competitive funding (especially Horizon 2020 and successor programmes) will be a key part of research strategy, but applied contract research requires a substantial client base, which will most likely go beyond Ireland. As such, these centres will only exist in areas where Ireland has (or will have) strong international research competitiveness.

Policy makers and stakeholders rightly stress the importance of avoiding the development of a broad RTO model in 'splendid isolation'. Besides a close coordination with the HEIs, its initiation should be accompanied by a strengthening of market orientation at the middle TRLs in other domains than the ones in which the RTO will operate. This should be done through an underlying strengthening of the Technology Centres.

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[130] Cf. NIBRT

9.2.2 The underlying strengthening of the Technology Centres

Implementing the broad RTO model would ultimately have substantial consequences for the system in Ireland. It would imply a strengthened market-oriented capacity in the upper middle and high TRLs in a small number of domains. But experiences in other countries show that these RTOs cannot flourish in isolation in their own technology and domain. Strengthening the market-oriented research centre capacity in other domains than the ones in which RTOs emerge is needed to encourage interdisciplinary research between fields important for the Irish industry and to assure a broad impact in the system. A parallel strengthening of the Technology Centres and links to SFI research Centres could accommodate this.

The underlying strengthening of the Technology Centres would be in line with recommendations in the recent independent evaluation of the Technology Centre programme, which included increased sunsetting, moving to a larger critical mass for these centres, to consider varying governance models with higher operational flexibility for certain centres[131] and to work on a succession model.[132] It would result in increased size (to around 50 FTE), opportunities to gain operational flexibility in terms of HR, and capital acquisition and an improved long-term perspective. The type of research functions provided will stay similar, although its increased size and sustainability also leads to increased possibilities for contract research and services.

Technology Centres will receive increased funding, resulting in larger, and fewer centres. This was also clearly recommended in the Evaluation of the EI/IDA Technology Centres.

9.3 Implications for the Irish research centre landscape

9.3.1 The underlying strengthening of the Technology Centres

Annual core funding would ultimately be about €2.5 to €2.75m per year per centre. This is more than the current individual EI/IDA Technology Centres receive. Apart from initial investments/lease investments in capital goods (currently owned by HEIs) this measure would therefore be budget neutral. Precise estimates of levels of investments would depend on domain, technology and the detailed description of needs (cf. Section 9.6).

As size of the strengthened Technology Centres would increase, a decrease in the number of Technology Centres would follow, especially in the early years. The extent to which the number of centres will decrease is up to the funding agencies, but assuming a 50FTE size, and an annual core funding of €2.5m to €2.75m, one would expect that *ceteris paribus* the current number of 15 centres would decrease to between 6 and 10 centres. Total RDI capacity (in terms of e.g. RDI FTE) increases, because of increased industry leverage. The latter requires an increase in operational independence where relevant as well as a longer funding horizons and an improved radar for the industry demand as identified in Chapter 5.

The implications of the underlying strengthening of the Technology Centres in the other parts of the system are limited. The SFI Centres will find that there are few implications except for increased opportunities to work closer together with the strengthened Technology Centres. The HEIs will find that the strengthened Technology Centres have more operational flexibility than most current Technology Centres. The overseas examples clearly show that HEIs should not be afraid of human capital losses.

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[131] Particularly ICMR/I2E2, which has also changed its governance arrangement in the course of 2014.

[132] Technology Centres Programme Interim Evaluation (2013) Enterprise Ireland/Frontline Evaluation, p. 7.

The strengthened Technology Centres will move up the TRLs and will perform different research functions (inevitable to reach the required industry leverage), which requires a different type of staff that responds to different KPIs than traditional academics. HEIs can still work closely with the strengthened research centres, which would result in increased opportunities in terms of education and training, publications, and research grants, all for relatively small investments from the HEIs. The sector-specific market-oriented research centres will notice little change, except for those that host currently EI/IDA Technology Centres.

9.3.2 The implementation of the RTO model

This measure could ultimately result in 2 to 4 relatively small to medium-size (250-500 FTE) RTOs in Ireland, which could in the long run could grow larger if successful (internationally). Annual core funding would ultimately be about €15m per year per RTO. This is about three times as much as Tyndall receives, slightly more than NIBRT, PMTC and SSPC receive together, and about a quarter of what Teagasc receives. Investments needed for this measure are therefore small apart from initial investments in capital goods. These investments would depend on the domain, technology, a detailed description of needs (cf. Section 9.6), and on the infrastructures and facilities already available.[133]

Introduction of a broad RTO model will have significant implications on the Irish research centre system. However, it should be noted that this measure is to some extent a rationalisation and simplification measure as various existing sector-specific centres could potentially fit under this model. Given the concentration of critical mass in such an RTO, it would not seem evident that there would be strengthened Technology Centres in the same field.

There would be a close relationship between the RTO and the associated HEI(s). However, the extent of operational flexibility will be much greater compared with the current SFI Research centres, and will look more like what the Fraunhofer Institutes have in Germany. Certain facilities could be shared, but there is a clear division of roles between the RTO and the HEI. In the medium to long run a clear mutually beneficial research ecosystem could strengthen the HEIs significantly. The HEIs can facilitate engineering MSc and PhD education, as well as professorships, while the RTOs can facilitate industry collaboration, and increased Horizon 2020 participation. Moreover, the RTO can open up its facilities for educational purposes.

Implications for the ambitious sector-specific centres might be substantial. Tyndall already closely fits the RTO model described above, and could shift relatively easily into this new research centre model, all other things being equal. Teagasc also has several characteristics of an RTO, although it also performs various other services besides research. Should NIBRT strengthen its research base substantially (which it is currently doing), it could also – in time – fit under the model, for instance with SSPC and PMTC.

It is important to note that this would not be a 'one size fits all' organisational model, and that the exact characteristics will depend on the implementation path that Ireland chooses to take in the coming years. Instead, a suite of broad RTOs may emerge over time with differing characteristics (in particular with respect to capital investment).

[133] For example, in some research areas a very significant capital investment may be required to allow for medium to high level TRL research to be conducted (e.g. manufacturing research), whereas other areas may require less capital equipment (e.g. service innovation research).

While governance models for different RTOs should be broadly similar, some flexibility on governance models should be allowed to ensure successful alignment of an RTO with the characteristics of different sectoral needs (e.g. high or low SME activity, speed of sectoral innovation cycles).[134]

9.4 The roles that key stakeholders would need to take to make this succeed

All stakeholders involved (EI; SFI; IDA; HEA) need to be aware that pursuing the two measures identified would require an adjustment of their current research centre strategies.

Enterprise Ireland/IDA Ireland. The recent Technology Centre evaluation showed that overall, the programme is operating (very) well, that individual centres are being managed effectively, resulting in a wide range of benefits. The evaluation also showed that Ireland currently has a greater number of Technology Centres than other countries of comparable size, and that sunsetting some centres, and increasing the size of others would be useful. These conclusions are closely in line with the outcomes of this report. This Roadmap would foresee that Enterprise Ireland and IDA decrease the number of Technology Centres down to 6 up to 10,[135] increasing their annual core funding to €2.5m to €2.75m per centre, increase their funding horizon, and provide opportunities for more for operational flexibility where relevant, which would allow for capital investments and strategic HR strategies by the centres. This would lead to increased industry leverage in the medium term. Parallel to that – in line with the recommendations of the mid-term evaluation of the Technology Centres – Enterprise Ireland and IDA Ireland would be advised to provide funding to a small cohort of the newer Centres that were not part of this review from years 1 to 2 onwards and determine if impact (and projected impact) after year three is commensurate with the increased resources. Enterprise Ireland and IDA Ireland should also consider if they want any of their Technology Centres to have a role in the broad RTO model. PTMC could be a good candidate due to the large opportunities in this sector, but a confirmation of sectoral demand would be required

SFI. Science Foundation Ireland funds oriented basic and more recently,[136] applied research in the areas of science, technology, engineering and mathematics (STEM). Even though SFI centre staff are responsive to industry needs in the lower TRLs; serving industry in higher TRLs has not necessarily been the focus of individual researchers funded through the SFI Research Centres programme. Relevant KPIs, as well as their long-term career objectives, are primarily aimed at academic excellence, and making this quantifiable through scientific publications. This is how university researchers operate all over the world, and there is no reason to assume Irish university researchers are any different. The system should respect SFI funded researchers for what they are good at: Generating new knowledge, developing cutting-edge technologies and collaborating with competitive enterprises through research spanning TRL 1-3, and to some extent TRL 4. It is crucial for both the strengthened Technology Centres and the broad RTOs that SFI continues its current role in the system and to feed into the new organisations, possibly through the Spokes programme.

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[134] Section 6.1.3 showed that the SOC instrument in Belgium should be considered a best practice in combining a rigid framework and a pragmatic approach depending on the sector.

[135] Frontline Consultants (2014). *Technology Centres Programme Interim Evaluation Report*. Final Report to Enterprise Ireland.

[136] 27 November 2013

IDA Ireland. Apart from what is mentioned under the discussion for Enterprise Ireland, direct changes for IDA Ireland would be limited. This would not be the case if NIBRT were to have an active role in one of the new broad RTOs, which would have some implications for IDA Ireland's policies. It also would not be the case if the new RTO were to focus on advanced manufacturing. IDA Ireland has a well-developed policy discourse in this field that follows from an Action Item from the Action Plans for jobs 2014 and 2015 requesting a business plan to support a cross-sector Centre in Advanced Manufacturing.

HEA. The increase in operational flexibility for the broad RTOs and to some extent the strengthened Technology Centres requires a rethinking of the relationship between HEIs and these centres. It is important that any detailed model development includes this as a key topic, as a close cooperation and coordination between HEIs and these centres is paramount to sustaining and improving not just the Irish research ecosystem but its human capital policy in general. Successful coordination and cooperation would offer increased opportunities in terms of education and training, publications, and research grants, all for relatively small investments from the HEIs. Experiences in other countries clearly show that RTOs and universities can benefit from each other. RTO research would focus on the middle and high TRL range, which is not where most of the university research is allocated. The RTOs can help HEIs in their STEM, engineering, MSc, and PhD education. RTOs usually also contribute to professorships, facilitate industry collaboration with universities in the lower TRLs, and help universities get Horizon 2020 funds. HEA should be aware that its coalition of HEIs will benefit from RTOs, as universities throughout the world benefit from RTO proximity.

9.5 Pilot area for the implementation of the Roadmap

Based on the data presented in Section 5, a concrete demand or market opportunity for the supply of more short-term applied and contract research, specifically in the sectors of Chemicals (Pharmaceuticals), Computers, Electronic and optical products and Medical Devices, and in terms of priority areas specifically ICT, Medical Devices and Manufacturing Technology (including process technology) areas was identified.

The table below translates these 'high potential RDI markets' to four concrete options for RTO pilots, based on a survey of existing centres and thereby the presence of a strong foundation for such a centre.

Figure 59 High-potential thematic areas for setting up an RTO

High potential thematic areas	Current main centres	Current centre base	Transition complexity
Computer, Electronic and optical products	Tyndall	Focused and large, serves as a good platform for an RTO.	Relatively low
Chemicals/Pharmaceuticals Manufacturing	SSPC, PMTC, NIBRT	Large, yet scattered, several funding agencies involved.	Medium, requires the merging of activities of NIBRT (biologics) and PMTC (pharmaceuticals). It would require additional investment.
Medical Devices	IPIC (partly)	Scattered and small	Difficult, would need additional investment.
Manufacturing Technology/Process technology	ICMR	Focused, yet relatively small, several funding agencies involved.	Would need additional investment. Well-developed policy discourse, business plans, and industry consensus available.

Source: Technopolis Group

DJEI asked Technopolis Group to identify a thematic area to test the broad RTO model proposed in a pilot initiative. Progression of the model on an evolutionary path would in the first instance be via a pilot approach. Ultimately, there is potentially room for 2-4 RTOs in Ireland, and all four thematic areas in Figure 59 qualify for that. Section 9.6 prescribes how the choice should be made by the relevant agencies on a level playing field basis.

9.6 Timeline with actions, and transition steps to be taken by the relevant stakeholders

9.6.1 The Irish Research Centre Landscape that can meet the needs identified in Chapter 3 and Chapter 5

Based on the measures outlined above, it is proposed that the market focused research centre landscape should evolve and introduce a third model initially on a pilot basis. The research centre landscape would therefore include:

- SFI Research Centres (RCs). These centres should continue on their existing trajectory, continuing to build strategic linkages with enterprise at the TRL1-4. The RC's main focus will continue to be on oriented basic and short and medium term problem driven research, academic led and industry informed, with industry influence achieved through collaborative research projects, funded through both the Centre and the Spokes funding programmes.
- Strengthened Technology Centres (TCs). Technology Centres should evolve towards a consolidation into fewer centres with increased critical mass, focused on industry led research in the TRL 4-7 range, with increasing capacity to deliver a broader range of research functions.
- A broad adapted RTO Model. These broad RTO(s) would deliver research across TRL 2-8 with emphasis on mid to high TRLs and RTO functions, including technology validation and testing services, pilot lines in the case of manufacturing research, contract research services and consultancy.

These three models, in combination, provide a framework for the industry facing research centre landscape in Ireland to evolve and develop in line with enterprise needs and the opportunity to do so in a manner that builds on strengths developed over the past 10-15 years. Together these models can provide a comprehensive and coherent portfolio of research capacity across the entire TRL scale and deliver the range of research functions offered to industry in leading market focused research ecosystems internationally.

9.6.2 Introduction to the steps towards this landscape

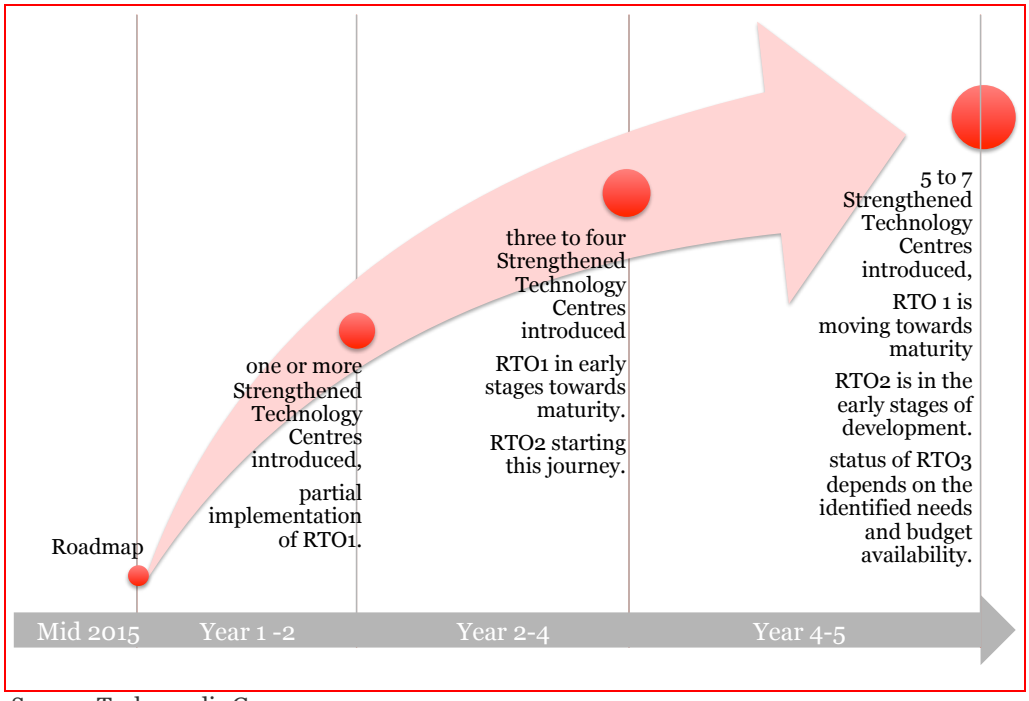
DJEI in consultation with EI, IDA Ireland, SFI and HEA should consider how best to manage the evolution of existing research centres towards the centre models proposed, involving wider stakeholders as necessary. This process could involve consolidation and/or expansion of existing technology centres and inviting expressions of interest from existing centres, currently operating in the areas identified in the report, as candidates for potential pilots to transition to a broad RTO model.

Oversight of a pilot initiative to transition centre(s) to a broad RTO model will be provided by DJEI working collaboratively with SFI, EI and IDA. Administration and management of RTO funding would be led by one coordinating agency (CA) leveraging particular competencies of other agencies. The CA should be identified at departmental level to ensure an optimal mandate.

Whilst this report shows that some evolution of the market focused research centre landscape through the strengthened Technology Centres can be funded through existing budgets, the feasibility of building additional capacity in the research centre landscape at the higher TRLs and provision of applied research services for industry in an RTO model is dependent on securing additional funding. Furthermore, ongoing commitment to growth in the HEI research base and investment in individual PI led research is critical to the ongoing competitiveness of Ireland's research ecosystem and implicitly underpins the report recommendations.

Figure 61 presents the proposed evolution of the Irish Research Centre Landscape between now and 2020.

Figure 60 Outlines proposed evolution of the Research Centre Landscape to 2020



Source: Technopolis Group

9.6.3 Stage 1: steps to be taken in the first year

In the first year significant steps should be taken to introduce one Strengthened Technology Centre and a pilot RTO initiative, RTO1. This can be in any of the fields identified in Figure 59, yet the transition complexity should be taken into account. The details are presented in the figure below. The main stakeholder for each step is presented in bold.

Figure 61 Transition steps to be taken within the next year regarding the evolution of centres

t	**Regarding the underlying strengthening of the Technology Centres**	**Regarding the implementation of the RTO model**
Year 1-2	**All**. Informing own organisations (DJEI; Agencies) of the upcoming changes in the system.	
	DJEI & CA. Find agreement with HEA/ SFI on the optimal relation between the HEI Research system, SFI Research Centres and Spokes, Technology Centres and potential RTO model, now and in the future.	
	EI & IDA. Updating Technology Centre funding model allowing for new strengthened Technology Centres	**DJEI**. Identification of the coordinating agency (CA) for the RTO model.
	EI & IDA. Consideration of the findings in Chapter 5 and Section 8.2 herein for a future Detailed Description of Needs (DDN)	**DJEI &CA with stakeholders**. Subject to additional funding being secured, establish legal framework for an RTO model, develop long term objectives, a description of needs, KPIs, milestones and deliverables linked to decisions for ongoing funding and based on experiences in established RTOs abroad. All based on Section 8.4.
	EI & IDA. Evolution/ introduction of at least one Strengthened Technology Centre	**DJEI &CA.** Progress evolution / transition of a centre to a broad adapted RTO as a pilot initiative, RTO1

Source Technopolis Group

Results after year 1: one or more Strengthened Technology Centres introduced, and the identification as well as partial implementation of RTO1 in Ireland.

9.6.4 Stage 2: steps to be taken in the years 2-4

In the years 2-4, two to three Strengthened Technology Centres should be introduced, RTO1 should be up and running, and steps should be taken towards a second broad adapted RTO pilot initiative, RTO2. When doing so, the lessons from RTO1 should be taken into account.

Figure 62 Transition steps to be taken in years 2 to 4

<table>
<tr><th>t</th><th>Regarding the underlying strengthening of the Technology Centres</th><th>Regarding the implementation of the RTO model</th></tr>
<tr><td rowspan="3">Years 2-4</td><td colspan="2">EI, IDA, SFI with DJEI. Biennial quantitative identification of research needs of companies in Ireland, based on methodologies used in this report to identify areas of high-potential RDI market (Chapter 5 of this report; Inclusion of questions on enterprise research needs in the Annual Business Survey of Enterprise Innovation is an efficient mechanism for this)

Based on that and additional stakeholder interviews, development of Detailed Description of Needs (DDN) for research support to enterprise in Ireland in the years 2-4 period.</td></tr>
<tr><td>EI & IDA. Evolution / introduction of two to three strengthened Technology Centres in response to the DDN drafted</td><td>DJEI & CA. Publish a Call for Proposals for a second adapted RTO pilot initiative in response to the legal framework set and to the DDN, subject to additional funding being secured. The DDN can use the model identified in Section 8.4.

The Call for Proposals should allow for a significant ramp-up phase, and allow third parties (e.g. (overseas) universities; (overseas) existing RTOs; and current Irish market-oriented research centres) to submit proposals. Parties should include such items as:
• their interpretation of the priority areas
• their interpretations of the key long term objectives of RTO2
• research functions that shall be offered by RTO2
• an operational model and a financial plan
• a proposal for concrete metrics, performance measures and monitoring procedures
• the governance model of RTO2
• HR policies of RTO2
• the relation with HEIs in Ireland
• the added value of their RTO2 to industry in Ireland.

Award procedures build on experiences abroad, and the CA should consider involving experts from abroad in this process.</td></tr>
<tr><td>DJEI &CA. Full implementation of RTO1. Introduction of a broad adapted RTO as a second pilot initiative, RTO2</td></tr>
</table>

Source Technopolis Group

Results after year 4: three to four Strengthened Technology Centres developed/ introduced, RTO1 in the early stages of development towards maturity. RTO2 is starting this journey.

9.6.5 Stage 3: steps to be taken in the years 4 and 5

In years 4-5 steps should be taken to introduce/ develop three additional Strengthened Technology Centre. RTO1 should be moving towards maturity, which also goes for RTO2. The possibility of a third broad adapted RTO initiative, RTO3 should be considered based on experience and learnings from previous pilot initiatives.

Figure 63 Transition steps to be taken in years 4 and 5

t	**Regarding the underlying strengthening of the Technology Centres**	**Regarding the implementation of the RTO model**
Years 4-5	**EI, IDA, SFI with DJEI**. Biennial quantitative identification of research needs of companies in Ireland, based on methodologies used in this report to identify areas of high-potential RDI market (Chapter 5 of this report; Inclusion of questions on enterprise research needs in the Annual Business Survey of Enterprise Innovation is an efficient mechanism for this) Based on that and additional stakeholder interviews, development of Detailed Description of Needs (DDN) for research support to enterprise in Ireland in the years 4-6 period.	
	EI & IDA. Evolution / introduction of two to three strengthened Technology Centres in response to the DDN drafted	**DJEI & CA** Assessment of the impacts of RTO1 and RTO2 and lessons to be learnt.
	EI & IDA. Assess demand for further strengthened Technology Centres.	**DJEI & CA**. If appropriate based on identified need and budget availability, publish a Call for Proposals, for RTO3. The Call for Proposals should allow for a significant ramp-up phase, and allow third parties (e.g. (overseas) universities; (overseas) existing RTOs; and current Irish market-oriented research centres) to submit proposals. Parties should clearly describe the added value of their proposal to industry in Ireland.

Source Technopolis Group

Results after year 5: five to seven Strengthened Technology Centres are introduced, RTO 1 is slowly moving towards maturity as described in Section 8.4, while RTO2 is in the early stages of development. The status of RTO3 depends on the identified needs and budget availability.

Appendix A List of those consulted

Pauline Mulligan	Department of Jobs, Enterprise and Innovation
Fionna Hallinan	Department of Jobs, Enterprise and Innovation
Keith O'Neill	Enterprise Ireland
Chantelle Kiernan	IDA Ireland
Marion Boland	Science Foundation Ireland
Roisin Cheshire	Science Foundation Ireland
Mark Fergusson	Science Foundation Ireland
J-C Despat	ICHEC
Michael Browne	ICHEC
Jason Roche	ICHEC
Declan Hughes	Department of Jobs, Enterprise and Innovation
John Dooley	Department of Jobs, Enterprise and Innovation
Lucy Cusack	Department of Jobs, Enterprise and Innovation
Ian Hughes	Department of Jobs, Enterprise and Innovation
Matt Moran	Ibec, PharmaChemical Ireland
Ned Costello	Irish University Association
Andrew Brownlee	Institutes of Technology Ireland
Imelda Lambkin	Enterprise Ireland
Muiris O'Connor	Higher Education Authority
Nicki O'Connor	Higher Education Authority
Tom Boland	Higher Education Authority
Sinead Keogh	Ibec, Irish Medical Devices Association
Dermot Curran	Department of Jobs, Enterprise and Innovation
Julie Sinnamon	Enterprise Ireland
Niall O'Donnellan	Enterprise Ireland
Kieran Drain	Tyndall
Barry Heavey	IDA Ireland
Gerry Byrne	University College Dublin
Gearóid Mooney	Enterprise Ireland

Appendix B TRL distributions for each of the Priority Areas

This Appendix presents a detailed analysis of the current market-oriented research capacity in Ireland for each of the Research Priority Areas. The data are presented as thousands of euros per year, per Research Priority Area. We distinguish between primary allocations, supporting allocations, and underpinning allocations.

Figure 64 Centre capacity (Primary capacity per Research Priority Areas)

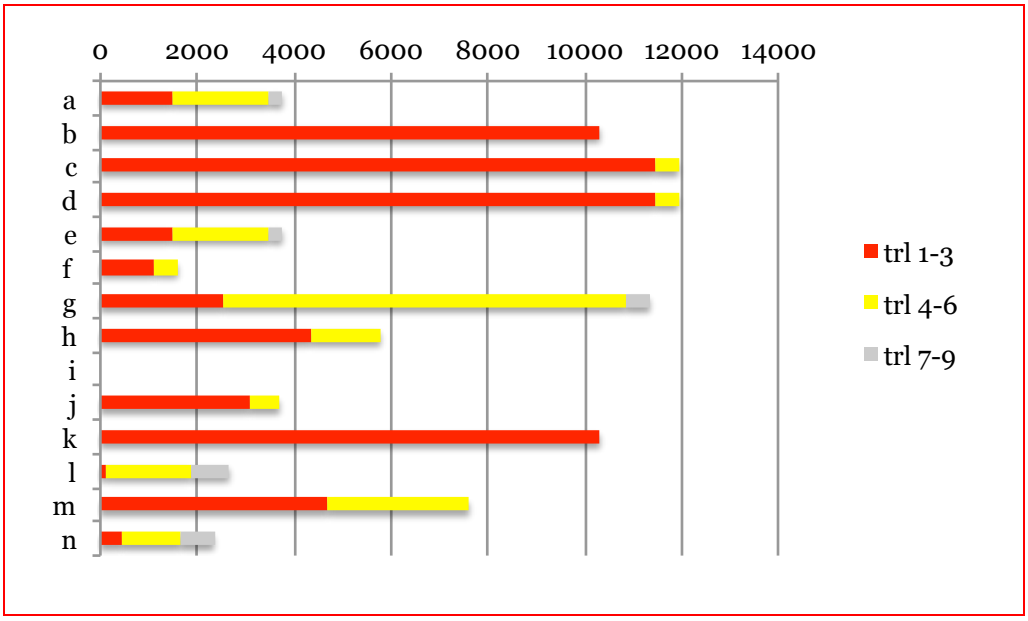


Figure 65 Centre capacity (Supporting capacity per Research Priority Areas)

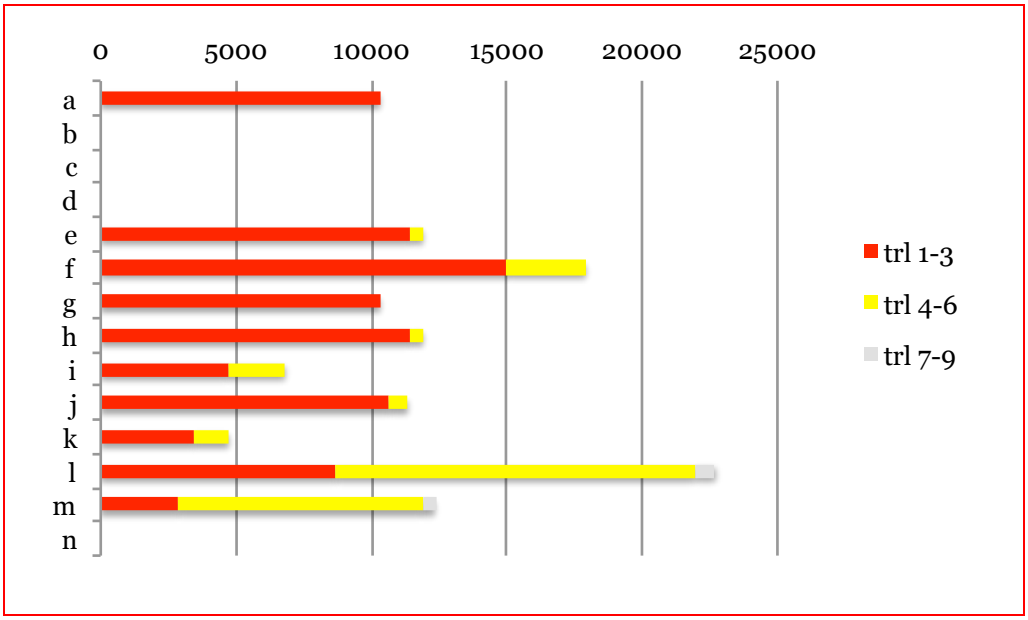
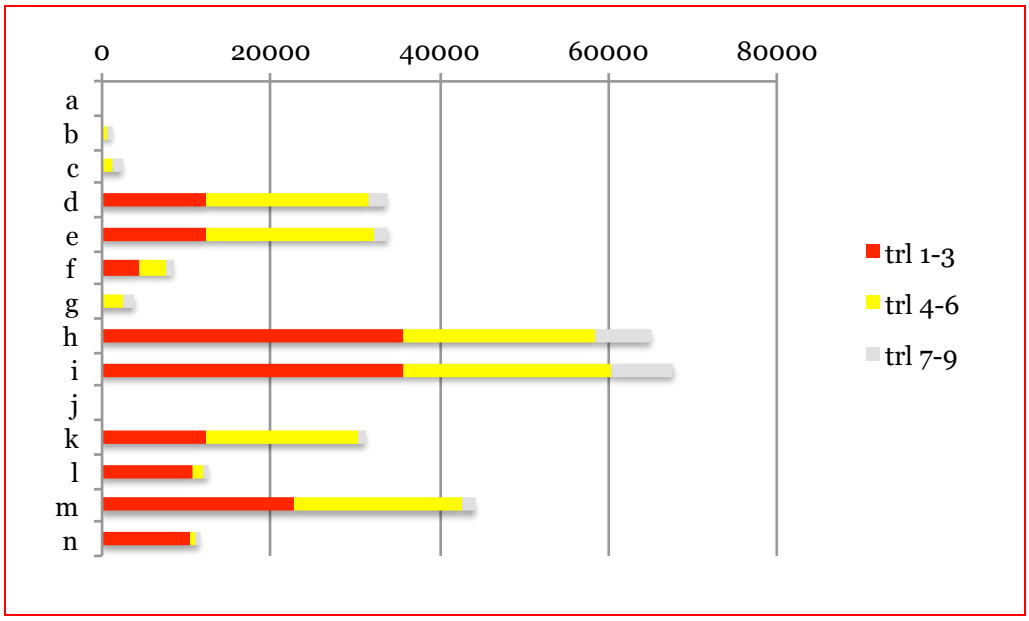


Figure 66 Centre capacity (Underpinning capacity per Research Priority Areas)



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