OECD Science, Technology and Industry Working Papers
2018/08

Trend-analysis of science,
technology and innovation
policies for BNCTs

Steffi Friedrichs

<https://dx.doi.org/10.1787/1566a6ce-en>

The release of this working paper has been authorised by Andrew Wyckoff, OECD Director for Science, Technology and Innovation and by Anthony Cox, OECD Director for Environment.

OECD Working Papers should not be reported as representing the official views of the OECD or of its member countries. The opinions expressed and arguments employed are those of the authors. Working Papers describe preliminary results or research in progress by the author(s) and are published to stimulate discussion on a broad range of issues on which the OECD works. Comments on Working Papers are welcomed, and may be sent to Directorate for Science, Technology and Innovation, OECD, 2 rue André-Pascal, 75775 Paris Cedex 16, France.

Note to Delegations:

This document is also available on O.N.E under the reference code:

DSTI/STP/BNCT(2017)5/FINAL

This document, as well as any data and any map included herein, are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

© OECD (2018)

You can copy, download or print OECD content for your own use, and you can include excerpts from OECD publications, databases and multimedia products in your own documents, presentations, blogs, websites and teaching materials, provided that suitable acknowledgment of OECD as source and copyright owner is given. All requests for commercial use and translation rights should be submitted to rights@oecd.org.

Table of Contents

Executive Summary	5
1. Introduction	6
1.1. Background	6
1.2. Definitions and key findings	7
1.2.1. Definitions and categorisation criteria	7
2. Background and context	11
3. Policy categorisation, analysis and discussion	14
3.1. Categorisation methodology and criteria	14
3.2. Technology-push <i>versus</i> application-pull	16
3.3. Technology-specificity	17
3.4. Policy instruments.....	17
4. Trends in policy developments	19
4.1. Trends in general STI policy developments	19
4.2. Trends in biotechnology policy developments	22
4.3. Trends in nanotechnology policy development	24
4.4. Trends in ICT policies development.....	26
5. Methodology.....	28
5.1. Data acquisition	28
5.2. Expansion of the BNCT-STIP Survey analysis	28
References	30
ANNEX A1: Example policy categorisation	32
Notes	36

Tables

Table 1. Overview of the directionality of policies analysed	14
Table 2. Overview of the “technology-specificity” of policies analysed	16

Figures

Figure 1. Illustration of the orthogonality between the concepts of “basic” <i>versus</i> “applied” and “technology-push” <i>versus</i> “application-pull”	12
Figure 2. Overview of (a) the directionality and (b) the technology-specificity of the policies analysed	15
Figure 3. Policy instruments employed by the technology policies analysed	18
Figure 4. General STI policy launches by (a) directionality and (b) policy instruments, 1984-2016	20
Figure 5. Biotechnology policy launches by (a) directionality and (b) policy instruments, 1976-2016	23
Figure 6. Nanotechnology policy launches by (a) directionality and (b) policy instruments, 1984-2016	25
Figure 7. ICT policy launches by (a) directionality and (b) policy instruments, 1991-2017	27

Executive Summary

This “Trend-Analysis of Science, Technology and Innovation Policies for Biotechnology, Nanotechnology and Converging Technologies (BNCT)” aims to analyse policies pertaining to nanotechnology and biotechnology over the past years. It also aims to study their character, i.e. does a policy aim to push a technology (“technology-push”) or to pull research towards a specific application (“application-pull”) and is a policy focussed on one technology field only or is it applicable to a wide range of technologies. In addition to the biotechnology and nanotechnology policies, the data-gathering and –analysis underlying this report was extended to policies on ICT (Information and Communication Technologies), in order to provide a comparator to the two technology fields of interest. In this analysis, a total of 192 individual policies devised by 49 countries or regions were identified and categorised according to their “technology-specificity” (i.e. the focus of a policy on biotechnology, nanotechnology, ICT and/or its applicability to the general STI (Science, Technology and Innovation) field) and according to “technology-push” and “application-pull”.

In general, technology-push policies seem to be favoured for young technology fields, while application-pull policies tend to be applied to more mature fields. In technology-specific policies, the percentage of pure application-pull policies is much lower than that observed for general STI policies. Most STI policies are technology-specific (i.e. the number of policies assigned to biotechnology, nanotechnology and/or ICT is around 20% higher than that assigned to the field of general STI). Most general STI policies, however, also mention a specific technology and are thus applicable to both the field of general STI and the field of the technology. In the case of biotechnology, nanotechnology and ICT, by contrast, at least one third of the policies are unique to the respective field, and only up to a quarter are shared with any other technology field.

Different instruments tend to track different technologies: Both biotechnology and nanotechnology, whose conduct commands high investments in infrastructures for syntheses and analyses (e.g. clean-rooms and powerful state-of-the-art microscopes), exhibit a high deployment of the “platforms and infrastructures” policy instrument. In the case of ICTs, the preferred policy instrument is “institutions and governance”. Policies supporting ICT hardware developments (e.g. supercomputers, broadband infrastructures, etc.) also require high investment. In general, however, ICT policies tend to be a lot more application-focused than bio- and nanotechnology policies.

The analyses presented in this report provide some indication of changes in policies for a given technology field over time: In the field of biotechnology, significantly more application-pull policies than technology-push policies have been launched in the past five years. The overall trend of nanotechnology policies launched over the past 33 years indicates a shift away from nanotechnology-push policies towards a preference for application-pull policies. Only the field of ICT shows significant support through pure technology-push policies in recent years.

1. Introduction

1.1. Background

Countries and regions are dedicating significant investments to the advancement of biotechnology, nanotechnology and ICT (information and communication technology). Recent comparative studies of the impact of policies, however, suggest that not every policy instrument is equally well-suited to create high economic impact from emerging technologies. Science, Technology and Innovation (STI) policy making could be significantly strengthened and advanced in both the speed and the *ex-ante* assessment of their impact, if it was possible to determine a pattern of change in STI policies with growing maturity and development of the technologies they address.

In 2015, the newly created Working Party on Biotechnology, Nanotechnology and Converging Technologies (BNCT) decided to commence its work on impact assessment of BNCTs and their policies by taking stock of the various different STI policies that address biotechnology, nanotechnology and converging technologies in the countries of its respective delegations.

The central aim of the BNCT's analysis was to first and foremost obtain an overview of the existence of national technology-specific policies for biotechnology and nanotechnology, as well as BNCT-specific policy instruments. In the case of nanotechnology, the last inventory of this kind had been conducted in 2008 (OECD, 2009^[1]), while an equivalent analysis of biotechnology-specific policies had not been conducted before.

In addition to analysing the longitudinal development of the number of policies pertaining to the advancement of biotechnology and nanotechnology over the past years, the BNCT aimed to obtain an insight into the directionality (i.e. “technology-push” *versus* “application-pull”) of such policies. The main questions asked at the onset of the analysis were:

- Have the number of STI policies that specifically aim to support the advancement of biotechnology or nanotechnology changed over time and with growing maturity of the technologies?
- Have the technology-specificity or the directionality of STI policies or the policy instruments they employ changed over time?

If it was possible to determine a pattern of change in STI policies with growing maturity and development of the technologies they are addressing, policy making could be advanced from being reactive to changing market needs to being more proactive and ultimately faster in the way it is supporting the technologies in question.

In order to gather the relevant policy information, an “International Survey on STI Policies for the Development of an ‘Inventory of Science, Technology and Innovation Policies for BNCT’” (BNCT-STIP Survey) was circulated to BNCT delegate countries

for completion in July 2016; the survey had been developed based on two former, established OECD questionnaires on STI policies:

- the OECD Working Party on Nanotechnology (WPN) “Inventory of National Science, Technology and Innovation Policies for Nanotechnology”, which had been developed by the WPN in 2008 (OECD, 2009^[1])
- the “EC (European Commission)/OECD International Survey and Database on Science, Technology and Innovation, edition 2014” (EC/OECD, 2014^[2]), which had been jointly developed by the OECD Directorate for Science, Technology and Innovation (DSTI), under the aegis of the OECD Committee for Scientific and Technological Policy (CSTP), and the European Commission Directorate General for Research & Innovation (DG RTD), in order to review the OECD’s hitherto used STI Outlook (STIO) questionnaire and the European Commission’s assessment of STI performances on Member State level.

In this analysis, a total of 192 individual policies devised by 49 countries or regions were identified and categorised according to their “technology-specificity” (i.e. the focus of a policy on biotechnology, nanotechnology, ICT and/or its applicability to the general STI field) and according to characteristics denoting a “technology-push” versus an “application-pull” directionality of the policies.

It must be noted that the reliability of the data collated for this report is somewhat affected by observation biases (i.e. the focus on recently launched policies caused by the dominance of 2014 and 2016 survey data). It is furthermore strongly dependent on the translation into English and the time resources of the officials who responded to the surveys on behalf of the economies and regions they represented.

1.2. Definitions and key findings

1.2.1. Definitions and categorisation criteria

The individual policies described in Member Countries’ survey replies were categorised according to their directionality (i.e. the characteristics differentiating “technology-push” from “application-pull” policies) and their generality (i.e. the antonym of a technology-specificity that limits a policy to be applicable to a specific technology field only). The following distinctions and categorisation criteria were applied:

- Policy directionality:
 - Pure “technology-push” policies typically aim to advance (i.e. push) a broad technology field (e.g. biotechnology, nanotechnology, ICT/digitalisation), independent of the application/market area the technology is commercialised in (i.e. health, agriculture, mining, energy, etc.). The potential impact of pushing a specific technology field (e.g. biotechnology) can lead to numerous applications in a variety of sectors (e.g. health care, food security, construction materials, biofuels).
 - Pure “technology-push” policies include those that are limited to supporting specific technology sub-categories only (e.g. stem-cell research, nanomedicine, software), unless the policy also specifies a restriction to a specific application sector.
 - Pure “application-pull” policies typically target (i.e. pull) the innovation into specific application areas (e.g. grand challenges (ageing society, climate change), sustainability, energy (storage), smart cities, aquaculture, broadband,

- open data, robotics) independent of the technology field that provides the innovative solution. The *ex ante* impact expected from an application-pull policy (e.g. cancer treatment) is open to be obtained by different technological solutions (e.g. biotechnology-based gene-therapies, nanotechnology-based medical devices), or by combinations of a number of technology fields (e.g. nanotechnology-based drug-delivery systems that carry biotechnology-based gene-therapies into the tumours).
- Pure “application-pull” policies include those that are targeted towards fostering specific down-stream elements of value chains (e.g. pilot plants, technology-transfer, clinical trials, ICT in SMEs).
- “Overlapping tech-push/app-pull” policies include characteristics of both “technology-push” and “application-pull” in the policy description.
- Policy Generality:
 - “Technology-specific” policies are typically limited to specific technology fields (e.g. biotechnology, digital technologies, microbiology, nanomedicine, software); such policies often mention the technology they are limited to in the policy title or description.
 - “Technology-specific” policies include those that are focussed on, and are thus limited to, a sub-area of science or technology (e.g. nanomedicine, molecular biology, stem cell research, software).
 - “General STI” (i.e. non-technology-specific) policies are either broadly applicable to several (or all) fields of science and technology (e.g. national STI policy), or are overarching policies that list a number technology fields (e.g. national development plans with special provisions for stem cell research, digitalisation and nanotechnology).

Directionality and generality categorisation decisions were based on the following three indicators: (a) the title of the policy, (b) the economy’s own declaration, which was often included as a descriptive element in the survey response, and (c) a brief description of the content of the policy. In rare cases, additional web-searches and/or communication with OECD colleagues, who had cleaned the EC/OECD data, was necessary, in order to enable a categorisation decision.

The concept of “technology-push” *versus* “application-pull” is akin to, but not entirely identical with that of “basic” *versus* “applied” science and technology. The latter terms are defined in the OECD’s Frascati Manual (OECD, 2015_[3]). The concept of “supply-side” *versus* “demand-side” policies also provides some parallels to the present analysis (OECD, 2011_[4]), but tends to focus more on the policy instruments applied by each policy category, while the categorisation of a policy into “technology-push” and “application-pull” policies depends on the policy’s focus on a technology field (or sub-field) *versus* its directionality towards a specific application (cf. Section 2.).

The distinction between “technology-push” and “application-pull” is hardly ever clear cut; ambiguous wording in the policy description or deliberate targeting of a policy to push a technology for a specific application area leads to many overlaps.¹ Possible overlaps between directionality categories were allowed and included in the analysis.

A number of key findings deserve to be emphasised:

- There is some evidence that technology-push policies are more common to technology fields that are still in their infancy, while application-pull policies tend to be developed to support mature technology fields: in technology-specific policies (such as policies that are focussed on the advancement of biotechnology or nanotechnology only), the percentage of pure application-pull policies is much lower than that observed for general STI policies (i.e. biotechnology: 38%, nanotechnology: 30%, ICT: 20%, general STI: 78%) (see Table 1 below).
- Technology-specific policies exhibit a much higher fraction of overlapping (tech-push/app-pull) policies than general STI policies (i.e. biotechnology: 39%, nanotechnology: 32%, ICT: 42%, general STI: 19%). Furthermore, general STI policies tend to focus on application-pull (i.e. 78 %) rather than technology-push (i.e. 3%) and overlapping tech-push/app-pull (i.e. 19%).
- Most STI policies are technology-specific (i.e. the number of policies assigned to biotechnology, nanotechnology and/or ICT is around 20% higher than that assigned to the field of general STI). Most general STI policies, however, also mention a specific technology and are thus applicable to both the field of general STI and the field of the technology. In the specific cases of biotechnology, nanotechnology and ICT, by contrast, at least one third of the policies are unique to the respective field, and only up to a quarter are shared with any other technology field.
- The policy instruments deployed by STI policies have diversified in the past 15 years. Preferred policy instruments are technology-specific: technology fields, such as biotechnology and nanotechnology, whose conduct commands high investments in infrastructures for syntheses and analyses (e.g. clean-rooms and powerful state-of-the-art microscopes), exhibit a high deployment of “platforms and infrastructures” as policy instruments. In the case of ICTs, which also requires high investment, the preferred policy instrument is “institutions and governance”. This difference could be an indication for the geographically wider-spread deployment of ICT policies, compared to the predominantly regional establishment of biotechnology and nanotechnology research infrastructures through geographically limited policies.
- Longitudinal analyses of policy launches in specific technology fields yields some evidence that countries are broadening the focus of technology policies through the inclusion of former technology-specific policies into overarching general STI policies. In the field of biotechnology, significantly more application-pull policies than technology-push policies have been launched in the past five years. The overall trend of nanotechnology policies launched over the past 33 years indicates a shift away from nanotechnology-push policies towards a preference for application-pull policies. Only the field of ICT shows significant support through pure technology-push policies in recent years.

Some overarching tendencies in policy development could be discerned, which allow conclusions with regard to the trends in policy change in different technology fields:

- The more mature a technology field, the lower the number of technology-push policies devised in its support.

- There is some indication that the more geographically wide-spread a policy is applied, the more often “institutions and governance” is the preferred instrument deployed by the policy.
- Policy instruments have diversified in recent years, and the relevant instrument deployed by a policy depends on the technology field addressed by the policy: specific material-based technology fields, such as biotechnology and nanotechnology tend to be supported on the regional level through “platforms and infrastructures”, while in the case of ICT, “institutions and governance” are the policy instruments of choice after “financial support”.

The analyses presented in this report provide some interesting indication of the change of policies for a given technology field over time. It seems advisable to follow up on this work with targeted, in-depth impact assessments of selected policies, such as those referred to in this report.

2. Background and context

The categorisation of policies into “technology-push” and “application-pull” policies draws parallels from the distinction of “supply-side” and “demand-side” STI policies; the latter have been thoroughly analysed and discussed in the 2008 “OECD Project on Demand-Side Innovation Policies”, as part of the “OECD Innovation Strategy” (OECD, 2011_[4]). The two concepts are, however, not fully equal, because the terms “supply-side” and “demand-side” policies tend to focus on the policy instruments applied by the relevant policies (e.g. supply-side: direct funding of business R&D, tax vouchers, risk capital sharing; demand-side: public procurement, regulation, standards), while the terms “technology-push” and “application-pull” describe the content focus of a policy to either push the advancement of a field (e.g. nanotechnology) (or a sub-field (e.g. nanomedicine)) of a technology, or pull the technology towards the advancement of a specific application area (e.g. drug delivery, energy storage); to distinction of a policy’s directionality to be either “technology-push” or “application-pull”, the instrument applied by the policy is of secondary consideration.

The concept of “technology-push” *versus* “application-pull” is furthermore akin to, but not entirely identical with that of “basic” versus “applied” research. The latter terms are defined in the OECD’s Frascati Manual (OECD, 2015_[3]). A recent paper and workshop by the OECD Committee of Scientific and Technological Policy (CSTP) elaborates the question of economic impact of both “basic” and “applied” research and explores the suitability of public research funding instruments to support the one and/or the other type of research, whilst strengthening excellence and breakthroughs in science (OECD, 2017_[5]; OECD, 2017_[6]).

By contrast, the policy analysis presented in this report is not an impact assessment of policies, but a categorisation of policies launched in support of a specific technology field, with the view to creating an inventory of technology policies that can be longitudinally analysed with regard to (a) their directionality (i.e. “technology-push” *versus* “application-pull”) and (b) their technology-specificity.

The analysis is focussed on policies for the following (specific) technology fields:

- biotechnology policies
- nanotechnology policies
- ICT/digitalisation policies
- (general STI policies (i.e. not technology-specific)).

The distinction of a policy to be either of “technology-push” or of “application-pull” directionality, combined with that of the policy’s generality (i.e. is a policy focussed on one technology field only or is it applicable to a wide range of technologies) is directed along innovation value-chains, while the differentiation between “basic” and “applied” research acts perpendicular to the value-chains. In other words, the categories assigned in this report identify individual strands of innovation value-chains that separate technologies from each other and that may further separate or merge along a value-chain,

while the concept of “basic” *versus* “applied” research separates an innovation value-chain into distinct stages. Figure 1 illustrates an example of this orthogonality.

Figure 1. Illustration of the orthogonality between the concepts of “basic” *versus* “applied” and “technology-push” *versus* “application-pull”

The terms “basic” and “applied” research define distinct stages of an innovation value-chain, while “technology-push” and “application-pull” policies separate parallel innovation/technology value-chains.

Note: Grey boxes and arrows indicate other possible value-chains that lie outside the example.

In its focus on the directionality and technology-specificity of policies, the current analysis is strictly an *ex ante* approach, because it considers the description of policies only, while their resulting impact is not being investigated. In this regard, it needs to be noted that “application-pull” policies can lead to basic research (i.e. “technology-push”) results, and *vice versa*, as has been documented and elaborated in the recent CSTP work (OECD, 2017_[6]; OECD, 2017_[5]).

Technology policy analysts found evidence that in recent years the balance between technology-push and application-pull policies has shifted towards the latter (Hoppmann, 2015_[7]). An in-depth study of the relationships between policy and innovation of both technology-push and application-pull policies found that domestic technology-push policies fostered innovation output within the domestic borders of a country or region only (Peters et al., 2012_[8]). Application-pull policies, on the other hand, triggered innovation output both within their own deployment region and in other economies in the form of foreign application-pull. The same study established that domestic application-pull policies did not lead to more national innovation output than foreign application-pull policies.² These findings have strong implications for the support of technologies that are

increasingly complex and prohibitively costly to be conducted by small communities, such as biotechnology, nanotechnology and ICT (OECD, 2017_[9]).

Application-pull policies are often deployed to foster and enhance the exploitation of technologies by firms. An analysis of the impact of both application-pull and technology-push policies on firms active in a specific field of technology, however, indicates that in the case of less mature technology fields, strong application-pull policies may eventually reduce the ability of firms active in the field to innovate, due to the loss of (support for) explorative activities that are required to develop an equipment infrastructure and knowledge-base for innovation in the technology field (Hoppmann et al., 2013_[10]).

In addition, it was found that the costs of technology exploitation through application-pull policies could be reduced, if policy makers allowed the underlying technologies to be applied in multiple sectors (Stephan et al., 2016_[11]). The multiple use of a single technology, however, tends to be affected by technology-push policies, and all but hindered by application-pull policies, because application-pull policies tend to stipulate a single use.

Countries and regions are dedicating significant investments to the advancement of technologies, and many are collaborating on a large scale to both support and conduct research into these technologies. The above mentioned detailed comparative studies of the impact of technology-push and application-pull policies, however, suggest that not every policy instrument is equally well-suited to operate on a multi-national level and to create high economic impact from emerging technologies.

3. Policy categorisation, analysis and discussion

For this report, a total of 192 individual policies devised by 49 countries or regions were identified and were categorised according to their “technology-specificity” (i.e. their focus on “biotechnology”, “nanotechnology”, “ICT” (information and communication technology) or “general STI” (general science, technology and innovation) or any combination of those four fields). In addition, they were distinguished and qualified according to the characteristics denoting a “technology-push” *versus* an “application-pull” directionality of the policy in question. A detailed description of the distinction criteria used during the policy categorisation is provided in Section 5. Methodology below. A set of example policy descriptions drawn from the original data set can be found in ANNEX A1.

3.1. Categorisation methodology and criteria

An overview of the individual policies found for all four technology fields and their categorisation into “technology-push”, “application-pull” or overlapping tech-push/app-pull is provided in Table 1, Table 2, and Figure 2. ANNEX A1 provides some selected examples of policies for each directionality category and technology field.

Hierarchically structured policy mixes, such as the “Strategic Research Centres” of Belgium (Flanders) are counted as both examples for categories of technology-push, application-pull and general STI and biotechnology-, nanotechnology- and ICT-specific policies.

Table 1 and Table 2 provide overviews of the policy categorisation statistics; these are illustrated in composite Figure 2 below.

Table 1. Overview of the directionality of policies analysed

Policy categorisation result statistics into exclusive “technology-push” *versus* “application-pull” (or an overlap between the two) for 192 policies across 49 countries or regions

	Total	Technology-push	Application-pull	Overlap (tech-push/app-pull)
General STI	64	2	50	12
Biotechnology	89	20	34	35
Nanotechnology	96	36	29	31
ICT	93	35	19	39
Total	342	93	132	117

Source: Own compilation from: 1. (OECD, 2009_[1]). 2. (EC/OECD, 2014_[2]). 3. (EC/OECD, 2016_[12]). 4. (OECD, 2016_[13]).

Figure 2. Overview of (a) the directionality and (b) the technology-specificity of the policies analysed

Source: Own compilation from: 1. (OECD, 2009_[1]), 2. (EC/OECD, 2014_[2]), 3. (EC/OECD, 2016_[12]), 4. (OECD, 2016_[13]).

Table 2. Overview of the “technology-specificity” of policies analysed

Number of individual policies by the “technology-specificity” of a policy (i.e. its focus on biotechnology, nanotechnology, ICT, or general STI (or any combination of the four fields)) for 192 policies across 49 countries or regions (entries in **bold** indicate the number of policies that are unique to a category)

	General STI	Biotechnology	Nanotechnology	ICT
General STI	30	28	33	25
Biotechnology	-	50	35	28
Nanotechnology	-	-	53	30
ICT	-	-	-	59

Source: Own compilation from: 1. (OECD, 2009_[11]). 2. (EC/OECD, 2014_[2]). 3. (EC/OECD, 2016_[12]). 4. (OECD, 2016_[13]).

3.2. Technology-push *versus* application-pull

General STI policies tend to be focussed on application-pull (i.e. 78% of all general STI policies are exclusively application-pull, compared to 3% technology-push, while 19% of general STI policies show both technology-push and application-pull characteristics), as illustrated in Figure 2(a). In the case of technology-specific policies, the percentage of pure application-pull policies is much lower than that observed for general STI policies (i.e. biotechnology: 38%, nanotechnology: 30%, ICT: 20%), and all technology fields show a much higher fraction of overlapping (tech-pus/app-pull) policies (i.e. biotechnology: 39%, nanotechnology: 32%, ICT: 42%).

Policies, such as the “National R&D programmes” policy of Estonia, which stipulates the support of “R&D and innovation in Energy Technology, ICT, Biotechnology, Health, Environment technology and Material technology”, illustrate that general STI policies do not need to be focussed on application-pull directionality by default (see also ANNEX A1).

The field of nanotechnology does not show significant differences between the number of technology-push, application-pull and overlapping policies. In the case of ICT policies, however, the numbers of technology-push and overlapping policies are significantly higher than that of pure application-pull policies.

Notwithstanding development of specific technologies (e.g. gene-editing) within each of the three broad technology fields of biotechnology, nanotechnology and ICT, the field of biotechnology (and the making of policies pertaining to its advancement) is much older than the fields of nanotechnology and ICT. Since the latter two represent the most recent technology fields to have become the object of policy making, the observed preference for technology-push policies over application-pull policies affecting these fields could be interpreted as an indication of the infancy of a technology field. Policy making in general STI and in biotechnology is much older than in the fields of nanotechnology and ICT: the term biotechnology was coined in the 1970s, while the idea of nanotechnology and ICT/digitalisation (under its current meaning and excluding the early reference to “computers”) started to be used in the 1990s (Silverstone, Hirsch and Morley, 1991_[14]; The Independent ICT in Schools Commission, 1997_[15]). Examples for these and other longitudinal trends in STI policy changes are discussed in Section 4. below in more detail.

3.3. Technology-specificity

Most policies are found to be technology-specific: 64 individual policies only are found to have characteristics of general STI (i.e. non-technology-specific) policies only, compared with 89, 96 and 93 policies indicating specificities for biotechnology, nanotechnology and ICT, respectively.

Figure 2(b) illustrates the overlap of policies between specific technology fields: General STI policies are almost evenly divided into those that are uniquely assigned to the general STI category and those that overlap with the fields of biotechnology, nanotechnology and ICT, respectively. This observation is not surprising, since the applied methodology stipulates that a policy, which addresses a broad range of applications and that also refers to a specific technology field, should be assigned to both the field of general STI and that of the referenced.

In the case of biotechnology, nanotechnology and ICT, by contrast, at least one third of the policies are unique to the respective field, and only up to a quarter are shared with any other technology field (see Figure 2(b) above).

3.4. Policy instruments

A key-element of public technology policies is the instrument that the policy deploys, in order to achieve its set objectives of technology advancement.³ Figure 3 shows the assignment of the six major policy instruments, separated by the directionality of the policy and the four technology fields distinguished:⁴ all four technology fields show a strong use of “financial support” in their technology policies. A distinction of policy instruments that pertain to technology-push policies or to application-pull policies, respectively, across all four technology fields cannot be discerned; there is, however, some indication that technology-push policies in the fields of both biotechnology and nanotechnology favour support *via* “platforms and infrastructures” over “institutions and governance”.

Figure 3. Policy instruments employed by the technology policies analysed

Percentage of the of instruments assigned to polices by directionality and by technology field

Note: Not all survey answers include information about the policy instruments employed, so that not all policies listed in Table 1 have been included in the computation of the figure above.

Source: Own compilation from: 1. (OECD, 2009_[1]), 2. (EC/OECD, 2014_[2]), 3. (EC/OECD, 2016_[12]), 4. (OECD, 2016_[13]).

The fields of biotechnology and nanotechnology differ slightly from those of ICT and general STI (technology-push): the former two technology fields (together with general STI application-pull policies) show a similarly high deployment of “platforms and infrastructures” instruments, which are, however, used with negligible frequency in ICT and general STI (technology-push) policies. One explanation for the phenomenon could be the often quoted high cost of biotechnology and nanotechnology research, which makes a public provision of central (and often shared, and virtual) infrastructures necessary (OECD, 2017_[9]). The field of ICT also commands high investment in research and development (e.g. for the expansion of broadband capacities or the development of supercomputers), but in the case of ICT, the relevant instrument of choice is identified as “institutions and governance” (cf. the relevant policies listed in ANNEX A1). This observation could be indicative of a geographically more wide-spread applicability of ICT policies, compared to the predominantly regionally deployed research centres, incubators and networks for biotechnology and nanotechnology.

4. Trends in policy developments

The trend analysis of each technology field, which is described in the next section, provides some indication of the increasing diversification in policy instruments that appears to have taken place since 2000: technology policies devised before 2000 exclusively consisted of the policy instrument “financial support”, “non-financial support” and “platforms and infrastructures”; since then, “institutions and governance” has become the second most favoured instrument (after “financial support”) in all technology fields. Support by “regulation” and “(public) procurement”, however, is rarely deployed.

The policy trend analysis conducted in this section shows that all technology fields exhibit a lack of policies launched before 2006. In the absence of any compelling explanation, it needs to be assumed that this development is based on an observation bias that has been caused by the limitation of this analysis to recent survey data, since most data stems from surveys conducted in 2014 and 2016/2017, respectively. The case of the data available on nanotechnology policies appears to strengthen this explanation: the nanotechnology policy data set, which includes the results of a 2008 source (OECD, 2009^[1]), shows more policies launched before 2006 than the other three technology fields.

4.1. Trends in general STI policy developments

General STI policies tend to be predominantly application-pull focussed, and very few general STI policies exhibit an overlap of both technology-push and application-pull characteristics (i.e. 19% of all general STI policies (cf. Figure 2(a)). This observation is supported by the longitudinal analysis of general STI policies launched over the last 40 years, illustrated in composite Figure 4.

Figure 4. General STI policy launches by (a) directionality and (b) policy instruments, 1984-2016

(a) Number of individual general STI policies launched in a given year by pure "technology-push" *versus* "application-pull" *versus* "overlapping (tech-push/app-pull)"

(b) Percentage of different types of instruments deployed by individual general STI policies launched in a given year

Note: Not all survey answers include information about the policy instruments employed, so that not all policies listed in Table 1 are included in the figure above.

Source: Own compilation from: 1. (OECD, 2009_[1]), 2. (EC/OECD, 2014_[2]), 3. (EC/OECD, 2016_[12]), 4. (OECD, 2016_[13]).

Since 1984, when the first general STI policy recorded in this analysis was implemented, only two pure general STI technology-push policies have been launched (cf. Table 1; one

of them (i.e. the “National R&D Programme” of Estonia; see ANNEX A1) does not stipulate a launch date, and is therefore not included in Figure 4). The overlapping tech-push/app-pull policy launched in 1984 is the “Flemish Strategic Research Centres”, which incorporated characteristics of both technology-push and application-pull (e.g. the strategic research centre “IMEC” was launched to address nanotechnology/nanoelectronics), and which is still in place today (see ANNEX A1). The highest number of general STI application-pull policies was launched in 2012 and 2013 (i.e. 8 and 9, respectively). The eight general STI policies launched in 2014 consist of seven application-pull policies and one overlapping tech-push/app-pull policy; they originate exclusively from eight European Union (EU) Member States that adopted the EU’s “Smart Specialisation Strategy (RIS3)” policy (namely the Czech Republic, Hungary, Latvia, Lithuania, Malta, Poland, Romania and Slovenia). This overarching European STI policy invites Member States to develop their own RIS3 strategies and thus create cohesion with the overarching EU’s RIS3 strategy, to ultimately obtain support of various different types from the European level. Only one EU Member State (i.e. Hungary) stipulated the inclusion of biotechnology, nanotechnology and ICT as technology-push characteristics into its RIS3 application-pull policy.

The EU’s “Smart Specialisation Strategy (RIS3)” is a classic example of a technology-unspecific general STI policy; the policy aims to encourage the setting of “vertical priorities regarding fields, technologies, [and] activities rather than generic priorities such as increasing cooperation between research and industry or improving human capital” (European Commission, 2014_[16]). The RIS3 policy explicitly incorporates the EU’s former (but still upheld) strategy for “Key Enabling Technologies (KETs)”, which since 2012 has prioritised the EU’s technology-push support of specific technologies (e.g. nanotechnology) and the application-pull targeting of specific application sectors (e.g. photonics, advanced manufacturing technologies, industrial biotechnology) (European Commission, 2012_[17]).

Amongst the 64 individual policies exhibiting general STI characteristics, three policies only were found to originate from the EU’s KETs policy launched in 2012 (i.e. the Czech Republic’s “TRIO” policy, Poland’s “business support system” and the European Union’s “KETs” policy).

The broadening of the focus of technology policies through the inclusion of technology-specific policies into overarching general STI policies appears to be representative of a trend in STI policy developments: both in the fields of biotechnology and nanotechnology, the number of new technology-specific policies peaked several years ago (i.e. for biotechnology in 2011 (see Figure 5), for nanotechnology in 2006 (see Figure 6)), while the number of newly launched general STI policies rose significantly between 2011 and 2013 and then appears to have dropped again (see Figure 4).

Indeed, some countries and regions appear to have in recent years switched from technology-specific technology-push policies to exclusively devising general STI policies with a strong application-pull focus: One example for such a change is France, which in 2008 reported to have had “several dedicated nanotechnology strategies in place in 2003 to 2006” (OECD, 2009_[11]); since 2013, however, France reports to focus on “34 Plans for Industrial Recovery” and on its “National Research Strategy”, indicating predominantly application-pull (e.g. “industrial”) and technology-unspecific policies (NOTE: As outlined in section 1.2.1 above, policies are categorised as “general STI” policies, if they simultaneously address more than one technology field; in this case, the set of “34 Plans

for Industrial Recovery” were counted as a single general STI policy, since no indication of specific provisions for biotechnology-, nanotechnology- or ICT-push had been given.).

Some regions have long-term policy portfolios in place that form a deliberate overlap between technology-specificity and broad support through general STI policies on one hand and overlapping technology-push and application-pull policies on the other. A typical example for this is the general STI policy underlying the “Flemish Strategic Research Centres”, which was initiated by the region of Flanders (Belgium) in 1984. This policy “pursues the development of some specific technologies or within some specific sectors” (EC/OECD, 2014_[2]) by fostering the creation of research centres in technology fields and/or application sectors. In this manner, a range of centres have been established that simultaneously follow technology-push and application-pull approaches (EC/OECD, 2014_[2]; OECD, 2016_[13]; Flanders, 2017_[18]):

- nanotechnology/electronics (centre: IMEC): established 1984
- biotechnology (centre: VIB): established 1996
- environment and energy and remote sensing (centre: VITO): established 1991
- ICT and digital research (centre: iMinds), established 2004 (merged with IMEC in 2016)
- smart manufacturing (centre: Flanders Make): established 2014.

Other examples of general STI policy portfolios with detailed provisions for specific technologies include the “Regional Growth Forum” in Denmark, under which action plans and initiatives for the support of specific technologies (e.g. ICT) and/or targeted applications (e.g. maritime environment, energy and climate, food) may be devised, the Slovenian “Development Centres”, and the European Union’s strategy for “Key-Enabling Technologies (KETs)”.

4.2. Trends in biotechnology policy developments

In the past five years, biotechnology-specific policies have focussed predominantly on application-pull strategies, as illustrated in Figure 5. In 2011, the highest number of biotechnology application-pull policies was launched (i.e. seven individual application-pull policies and four overlapping tech-push/app-pull policies in a single year, followed by six and three, respectively, in 2012), while the maximum number of newly launched technology-push policies was three in one year (i.e. 2012).

Examples of biotechnology-push policies include the “Biotechnology Development Policy” of Brazil, which, launched in 2007, aims to support research and innovation in “convergent and enabling technologies (including biotechnology and nanotechnology)” (OECD, 2016_[13]), and the “Genome Canada” initiative: a “not-for-profit cooperation dedicated to accelerating the development of Canadian research capacity in genomics”, launched in 2000 (see ANNEX A1).

Examples of biotechnology policies that overlap between technology-push and application-pull include the European Commission’s “Life Science and Biotechnology – a Strategy for Europe” policy, which was launched in 2002, and the “Israeli Bio-Plan” (2000-2010), which is aimed at “improving existing biotechnology and technology for water, [by] enabling the efficient transfer of technology from basic research to the industry, [...] as well as supporting scientific infrastructure” (OECD, 2016_[13]) (see ANNEX A1).

Figure 5. Biotechnology policy launches by (a) directionality and (b) policy instruments, 1976-2016

Note: Not all survey answers include information about the policy instruments employed, so that not all policies listed in Table 1 are included in the figure above.

Source: Own compilation from: 1. (OECD, 2009_[1]), 2. (EC/OECD, 2014_[2]), 3. (EC/OECD, 2016_[12]), 4. (OECD, 2016_[13]).

Italy's policy on "Advanced Life Science in Italy (ALISEI)", launched in 2012, and the UK's initiative entitled "Biomedical Catalyst (BMC)", also launched in 2012, are both examples for exclusively application-pull policies for biotechnology; both policies target specific advances in the medical sector through support of biotechnology (see ANNEX A1).

4.3. Trends in nanotechnology policy development

The analysis of the field of nanotechnology includes an additional data source (i.e. the 2008 "Inventory of National Science, Technology and Innovation Policies for Nanotechnology" (OECD, 2009_[1])) compared to the other three technology fields considered in this report. Especially older nanotechnology policies have been identified in the 2008 WPN inventory. Assuming that no observation or reporting bias skewed the answers provided to the 2008 survey, the overall trend of nanotechnology policies launched over the 33 years indicates a shift away from nanotechnology-push policies towards a preference for application-pull policies.

The largest number of technology-push policies for nanotechnology was launched in 2006 (i.e. six individual pure technology-push policies and four overlapping tech-push/app-pull policies within one year); the pure technology-push policies include Germany's "Nano Initiative – Action Plan 2010", Norway's "National Strategy for Nanoscience and Nanotechnology", and the "International Iberian Nanotechnology Laboratory" in Portugal (OECD, 2009_[1]) (see ANNEX A1).

Examples for nanotechnology policies that include both technology-push and application-pull characteristics include "i-Net Basel" (Switzerland), launched in 2012, which focuses on nanotechnology, greentech and ICT, and the "National Nanotechnology Centre (NANOTEC)" in Thailand, established in 2003, which invests in the "promotion to production of nano- materials or from nano-materials" (OECD, 2009_[1]) (see ANNEX A1).

The launch of technology-push policies in nanotechnology was more extensive than that of application-pull and overlapping tech-push/app-pull policies until 2007, as illustrated in Figure 6. Since then, the reverse appears to be true: in 2012, five individual nanotechnology application-pull policies and four overlapping tech-push/app-pull policies were launched; these include the European Union's "KETs" policy and Norway's "NANO2021" policy, which are examples for overlapping (tech-push/app-pull) policies, because they both specifically push nanotechnology as a technology field, but also target the advancement of the technology for individual sectors, such as advanced materials (EC/OECD, 2014_[2]) (see ANNEX A1).

Some countries and regions have recently launched policies focussed on the nanomaterials "graphene" only, such as Poland's "GRAF-TECH Programme", launched 2012, and Sweden's "SIO Grafen Strategic Innovation Programme", launched 2014 (EC/OECD, 2014_[2]; OECD, 2016_[13]); in the case of Poland, the policy's stress on industrial sectors and products affords a categorisation as a tech-push/app-pull policy, whereas the Swedish policy shows pure technology-push directionality.

Figure 6. Nanotechnology policy launches by (a) directionality and (b) policy instruments, 1984-2016

Note: Not all survey answers include information about the policy instruments employed, so that not all policies listed in Table 1 are included in the figure above.

Source: Own compilation from: 1. (OECD, 2009_[1]), 2. (EC/OECD, 2014_[2]), 3. (EC/OECD, 2016_[12]), 4. (OECD, 2016_[13]).

Examples for pure application-pull policies for nanotechnology are the Turkish “National Science, Technology and Innovation Strategy” (2011-2016), which stipulates that “[n]anotechnology is considered as a horizontal [...]; hence it is implicitly taken into consideration within all priority areas (automotive, machinery and manufacturing technologies, energy, information and communications technology, water, food, defence, and space) [and] most specifically in ICT and health”, and the “Holst Centre” in the Netherlands, which is a public-private-partnership that shares research on wireless sensor technology and flexible electronics (EC/OECD, 2014_[2]) (see ANNEX A1).

4.4. Trends in ICT policies development

ICT policies appear to be much less dominated by a (recent) focus on application-pull over technology-push than is the case for biotechnology and nanotechnology: since the first recorded launch of a technology-push ICT policy in 1991, more technology-push policies than application-pull policies were launched for ICTs (see Figure 7).

Since 2011, the number of pure application-pull policies has increased, and the number of newly launched pure technology-push policies has always at least been matched by that of the pure application-pull policies and overlapping tech-push/app-pull policies. Nevertheless, the number of technology-push policies for ICTs launched in recent years is significantly higher than for the other three technology fields.

Pure technology-push policies for ICTs and digitalisation include the “Impulse Programmes” of Belgium (Brussels Capital), launched in 2006, which aims to “strengthen the research potential [...] in three thematic areas: ICT, Life Sciences and Environment”, the Brazilian “Finance Subsidies for ICT Sector R&D”, launched in 2012, and the “CINECA Supercomputing Centre” in Italy (EC/OECD, 2014_[2]; EC/OECD, 2016_[12]) (see ANNEX A1).

Examples for ICT policies that include both technology-push and application-pull characteristics are the Italian “National Broadband Plan” (2009-2013), which aims to improve “ICT services and infrastructures at national level”, as well its follow-up plan, the Italian “Strategic Plan Ultrabroadband” (2013-2020) for “the diffusion of ultra-broadband technologies” (EC/OECD, 2014_[2]) (see ANNEX A1).

The “QUTECH Dutch Institute for Quantum Technology”, launched 2015, is an example for an application-focussed technology policy for ICTs, because it encourages and supports research and innovation in both nanotechnology, ICTs and other disciplines (EC/OECD, 2016_[12]) (see ANNEX A1).

Figure 7. ICT policy launches by (a) directionality and (b) policy instruments, 1991-2017

Note: Not all survey answers include information about the policy instruments employed, so that not all policies listed in Table 1 are included in the figure above.

Source: Own compilation from: 1. (OECD, 2009_[1]). 2. (EC/OECD, 2014_[2]). 3. (EC/OECD, 2016_[12]). 4. (OECD, 2016_[13]).

5. Methodology

5.1. Data acquisition

In 2016, the newly created Working Party on BNCTs developed and circulated an “International Survey on STI Policies for the Development of an ‘Inventory of Science, Technology and Innovation Policies for BNCT’” (BNCT-STIP Survey), in order to stock of the various different science, technology and innovation policies that address biotechnology, nanotechnology and converging technologies in the countries of its respective delegations (OECD, 2016_[13]).

The BNCT-STIP Survey had been developed based on two former, established OECD questionnaires on STI policies:

- the OECD Working Party on Nanotechnology (WPN) “Inventory of National Science, Technology and Innovation Policies for Nanotechnology”, which had been developed by the WPN in 2008 (OECD, 2009_[1])
- the “EC (European Commission)/OECD International Survey and Database on Science, Technology and Innovation, edition 2014” (EC/OECD, 2014_[2]), which had been jointly developed by the OECD Directorate for Science, Technology and Innovation (DSTI), under the aegis of the OECD Committee for Scientific and Technological Policy (CSTP), and the European Commission Directorate General for Research & Innovation (DG RTD), in order to review the OECD’s hitherto used STI Outlook (STIO) questionnaire and the European Commission’s assessment of STI performances on Member State level.

The BNCT-STIP Survey aimed to first and foremost take stock of the existence of national technology-specific policies for biotechnology and nanotechnology, as well as BNCT-specific policy instruments; in the case of nanotechnology, the last inventory of this kind had been conducted in 2008 (OECD, 2009_[1]), while an equivalent analysis of biotechnology-specific policies had not been conducted before.

It needs to be noted that the data acquisition applied may be prone to some bias: since the first member state contact point is often with the relevant research ministry of a member state, the survey might miss relevant policies that fall under the responsibility of other ministries.

5.2. Expansion of the BNCT-STIP Survey analysis

By May 2017, responses from 21 BNCT delegation countries or regions had been received to the BNCT-STIP Survey, including OECD member countries, individual regions of OECD member countries and OECD guest member countries.

In order to increase the sample size and thereby the relevance of the analysis, it was decided to expand the analysis to non-BNCT delegations by including all relevant responses to the OECD 2008 “Inventory of National Science, Technology and Innovation Policies for Nanotechnology” as well as the “EC (European Commission)/OECD

International Survey and Database on Science, Technology and Innovation, edition 2014” and “EC (European Commission)/OECD International Survey and Database on Science, Technology and Innovation, edition 2016” in the analysis (OECD, 2009_[1]; EC/OECD, 2014_[2]; EC/OECD, 2016_[12]).

In total, the following data-sets (designed and analysed to focus on specific technologies only) were considered in the analysis presented in this document:⁵

1. 2008 “Inventory of National Science, Technology and Innovation Policies for Nanotechnology” (nanotechnology only) (OECD, 2009_[1])
2. 2014 “EC (European Commission)/OECD International Survey and Database on Science, Technology and Innovation, edition 2014” (Section D: biotechnology (D1), nanotechnology (D2), ICTs (D3)) (EC/OECD, 2014_[2])
3. 2016 “EC (European Commission)/OECD International Survey and Database on Science, Technology and Innovation, edition 2016” (Section D: biotechnology (D1-1), nanotechnology (D1-2), ICTs (D1-3)) (EC/OECD, 2016_[12])
4. 2016/2017 “BNCT-STIP Survey: International Survey on STI Policies for the Development of an ‘Inventory of Science, Technology and Innovation Policies of for BNCT’” (biotechnology, nanotechnology and converging technologies) (OECD, 2016_[13])

References

- EC/OECD (2014), *EC (European Commission)/OECD International Survey and Database on Science, Technology and Innovation Policies, edition 2014*, <http://qdd.oecd.org/subject.aspx?Subject=a2ebc2a0-b8dc-4d1a-82be-3fea780b86a6> (accessed on 12 October 2017). [2]
- EC/OECD (2016), *EC (European Commission)/OECD International Survey and Database on Science, Technology and Innovation Policies, edition 2016*, http://qdd.oecd.org/subject.aspx?Subject=STIO_2016 (accessed on 12 October 2017). [12]
- European Commission (2012), *A European strategy for Key Enabling Technologies – A bridge to growth and jobs [COM(2012) 341 final]*, <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0341&from=EN> (accessed on 15 October 2017). [17]
- European Commission (2014), *Cohesion Policy 2014-2020: National/Regional Innovation Strategies for Smart Specialisation (RIS3)*, http://ec.europa.eu/regional_policy/sources/docgener/informat/2014/smart_specialisation_en.pdf (accessed on 15 October 2017). [16]
- Flanders (2017), *Research centers and scientific institutes | Invest in Flanders*, <https://www.flandersinvestmentandtrade.com/invest/en/investing-in-flanders/rd-and-innovation/flanders%E2%80%99-world-class-research-centers-and-scientific> (accessed on 17 October 2017). [18]
- Hoppmann, J. et al. (2013), “The two faces of market support - How deployment policies affect technological exploration and exploitation in the solar photovoltaic industry”, *Research Policy*, <http://dx.doi.org/10.1016/j.respol.2013.01.002>. [10]
- Hoppmann, J. (2015), “The Role of Deployment Policies in Fostering Innovation for Clean Energy Technologies”, *Business & Society*, Vol. 54/4, pp. 540-558, <http://dx.doi.org/10.1177/0007650314558042>. [7]
- Jacob, M. (2013), *Public research funding instruments and modalities (Programme on Innovation, Higher Education and Research for Development (IHERD))*. [20]
- OECD (2009), “Inventory of National Science, Technology and Innovation Policies for Nanotechnology”, <http://www.oecd.org/sti/nano/43348394.pdf> (accessed on 12 October 2017). [11]
- OECD (2011), *OECD Innovation Policy Platform The issue in a nutshell*, OECD, <http://www.oecd.org/innovation/policyplatform> (accessed on 23 June 2017). [19]
- OECD (2011), *Demand-side Innovation Policies*, OECD Publishing, Paris, <http://dx.doi.org/10.1787/9789264098886-en>. [4]
- OECD (2015), *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on* [3]

Research and Experimental Development, OECD Publishing, Paris,
<http://dx.doi.org/10.1787/9789264239012-en>.

- OECD (2016), *BNCT-STIP Survey: International Survey on STI Policies for the Development of an 'Inventory of Science, Technology and Innovation Policies of for BNCT'*, (internal document). [13]
- OECD (2017), *The Next Production Revolution: Implications for Governments and Business*, OECD Publishing, Paris, <http://dx.doi.org/10.1787/9789264271036-en>. [9]
- OECD (2017), *Background Paper - Fostering Research to serve Society and the Economy*, (internal document). [5]
- OECD (2017), *Draft Programme of the CSTP Workshop on "Funding public research to serve society and the economy -What budgetary balances and instruments?"*, (internal document). [6]
- Peters, M. et al. (2012), "The impact of technology-push and demand-pull policies on technical change - Does the locus of policies matter?", *Research Policy*, <http://dx.doi.org/10.1016/j.respol.2012.02.004>. [8]
- Silverstone, R., E. Hirsch and D. Morley (1991), "Listening to a long conversation: An ethnographic approach to the study of information and communication technologies in the home", *Cultural Studies*, Vol. 5/2, pp. 204-227, <http://dx.doi.org/10.1080/09502389100490171>. [14]
- Stephan, A. et al. (2016), "Limiting the public cost of stationary battery deployment by combining applications", *Nature Energy*, Vol. 1/7, p. 16079, <http://dx.doi.org/10.1038/nenergy.2016.79>. [11]
- The Independent ICT in Schools Commission, U. (1997), *Information and Communications Technology in UK Schools - An Independent Inquiry*. [15]

ANNEX A1: Example policy categorisation

Table A1. Selected policies illustrating the categorisation process

Exemplary policies selected from the data set of 192 policies across 49 countries or regions by (a) the directionality and (b) the specificity of the policy analysed; policies in *italics* represent those that are reproduced in more than one technology-specific column.

Policy categorisation	Technology-specificity			
	Biotechnology-specific	Nanotechnology-specific	ICT-specific	Unspecific (i.e. general STI policies)
Technology-push (unambiguous)	Genome Canada is a not-for-profit corporation dedicated to accelerating the development of Canadian research capacity in genomics.	International Iberian Nanotechnology Laboratory (Portugal)	Finance Subsidies for ICT Sector R&D (Brazil): The objective of the initiative is to promote R&D in ICTs sector.	
		National Nanotechnology Programme (Brazil)	CINECA supercomputing centre (Italy): TOP500-list of the most powerful supercomputers in the world.	
	<i>Biotechnology Development Policy (Brazil)</i>	<i>Biotechnology Development Policy (Brazil)</i>		
	<ul style="list-style-type: none"> support of R,D&I in convergent and enabling technologies (including biotechnology and nanotechnology) 	<ul style="list-style-type: none"> support of R,D&I in convergent and enabling technologies (including biotechnology and nanotechnology) 		
	<i>Impulse Programmes (Belgium (Brussels Capital))</i> : strengthen the research potential and the regional know-how in three thematic areas: <i>ICT, Life Sciences and Environment</i> .	<i>Impulse Programmes (Belgium (Brussels Capital))</i> : strengthen the research potential and the regional know-how in three thematic areas: <i>ICT, Life Sciences and Environment</i> .	<i>Impulse Programmes (Belgium (Brussels Capital))</i> : strengthen the research potential and the regional know-how in three thematic areas: <i>ICT, Life Sciences and Environment</i> .	
	<i>National R&D programmes (Estonia)</i> :	<i>National R&D programmes (Estonia)</i> :	<i>National R&D programmes (Estonia)</i> :	<i>National R&D programmes (Estonia)</i> :
	<ul style="list-style-type: none"> to support R&D and innovation in Energy Technology, ICT, Biotechnology, Health, Environment technology and Material technology. 	<ul style="list-style-type: none"> to support R&D and innovation in Energy Technology, ICT, Biotechnology, Health, Environment technology and Material technology. 	<ul style="list-style-type: none"> to support R&D and innovation in Energy Technology, ICT, Biotechnology, Health, Environment technology and Material technology. 	<ul style="list-style-type: none"> to support R&D and innovation in Energy Technology, ICT, Biotechnology, Health, Environment technology and Material technology.

Policy categorisation	Technology-specificity			
	Biotechnology-specific	Nanotechnology-specific	ICT-specific	Unspecific (i.e. general STI policies)
Overlap: technology-push / application pull	Life-Science and Biotechnology - a strategy for Europe (EU): <ul style="list-style-type: none"> strong scientific, technological and innovation base in biotechnology societal challenge food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy 	i-Net Basel (Switzerland): focusses on nanotechnology, greentech and ICT	i-Net Basel (Switzerland): focusses on nanotechnology, greentech and ICT	
	Israeli Bio-Plan (Israel): <ul style="list-style-type: none"> improving the existing biotechnology and technology for water enabling the efficient transfer of technology from basic research to the industry, as well as supporting a state-of-the-art physical, regulatory and scientific infrastructure. 	National Nanotechnology Center (NANOTEC) (Thailand): <ul style="list-style-type: none"> national R&D centre funding agency gives investment promotion to production of nano-materials or products from nano-materials 	National Broadband Plan (Italy): <ul style="list-style-type: none"> improving ICT services and infrastructures at national level. 	
			Strategic Plan Ultrabroadband (Italy): for the diffusion of ultra-broadband technologies in the southern regions of Italy.	
	European Strategy for Key-Enabling Technologies (EU): <i>KETs are a group of six technologies: micro and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies.</i> NANO2021 (Norway): <ul style="list-style-type: none"> national knowledge base within nanotechnology and advanced materials concentrate on opportunities within national priority areas such as energy and the environment, health, food, the maritime and marine sectors, ICT, biotechnology and advanced 	European Strategy for Key-Enabling Technologies (EU): <i>KETs are a group of six technologies: micro and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies.</i> NANO2021 (Norway): <ul style="list-style-type: none"> national knowledge base within nanotechnology and advanced materials concentrate on opportunities within national priority areas such as energy and the environment, health, food, the maritime and marine sectors, ICT, 		European Strategy for Key-Enabling Technologies (EU): <i>KETs are a group of six technologies: micro and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies.</i> NANO2021 (Norway): <ul style="list-style-type: none"> national knowledge base within nanotechnology and advanced materials concentrate on opportunities within national priority areas such as energy and the environment, health, food, the maritime and marine sectors, ICT,

Policy categorisation	Technology-specificity			
	Biotechnology-specific materials.	Nanotechnology-specific biotechnology and advanced materials.	ICT-specific	Unspecific (i.e. general STI policies) biotechnology and advanced materials.
	Development Centres (Slovenia): <ul style="list-style-type: none"> • New materials • Wood-processing industry • ICT • Pharmacy and biotechnology • Energy • Electricity industry and electronics • Automobile industry 	Development Centres (Slovenia): <ul style="list-style-type: none"> • New materials • Wood-processing industry • ICT • Pharmacy and biotechnology • Energy • Electricity industry and electronics • Automobile industry 	Development Centres (Slovenia): <ul style="list-style-type: none"> • New materials • Wood-processing industry • ICT • Pharmacy and biotechnology • Energy • Electricity industry and electronics • Automobile industry 	Development Centres (Slovenia): <ul style="list-style-type: none"> • New materials • Wood-processing industry • ICT • Pharmacy and biotechnology • Energy • Electricity industry and electronics • Automobile industry
	Flemish Strategic Research Centres (Belgium (Flanders)): <ul style="list-style-type: none"> • The Strategic Research Centre VIB is active in biotechnology (VIB) (1996); nanotechnology/electronics (Imec) (1984); • environment and energy and remote sensing (VITO) (1991); • ICT and digital research (iMinds) (2004); smart manufacturing (Flanders Make)(2014) 	Flemish Strategic Research Centres (Belgium (Flanders)): <ul style="list-style-type: none"> • The Strategic Research Centre VIB is active in biotechnology (VIB) (1996); nanotechnology/electronics (Imec) (1984); • environment and energy and remote sensing (VITO) (1991); • ICT and digital research (iMinds) (2004); smart manufacturing (Flanders Make)(2014) 	Flemish Strategic Research Centres (Belgium (Flanders)): <ul style="list-style-type: none"> • The Strategic Research Centre VIB is active in biotechnology (VIB) (1996); nanotechnology/electronics (Imec) (1984); • environment and energy and remote sensing (VITO) (1991); • ICT and digital research (iMinds) (2004); smart manufacturing (Flanders Make)(2014) 	Flemish Strategic Research Centres (Belgium (Flanders)): <ul style="list-style-type: none"> • The Strategic Research Centre VIB is active in biotechnology (VIB) (1996); nanotechnology/electronics (Imec) (1984); • environment and energy and remote sensing (VITO) (1991); • ICT and digital research (iMinds) (2004); smart manufacturing (Flanders Make)(2014)

Policy categorisation	Technology-specificity			
	Biotechnology-specific	Nanotechnology-specific	ICT-specific	Unspecific (i.e. general STI policies)
Application-pull (unambiguous)	Biomedical Catalyst (BMC) (UK): aims to deliver growth to the UK life sciences sector	Holst Centre (Netherlands): • a public-private partnership on shared technology roadmaps and research programmes in the area of wireless sensor technology and flexible electronics.	National Smart Specialization Program (Chile): Smart Industries	34 Plans for Industrial Recovery (France): to build a new and competitive industry in France
	Advanced Life Science in Italy (ALISEI): • transferring knowledge and technologies from multidisciplinary research to the pharmaceutical and biomedical industry • share best practices [among] public and private stakeholders in the life science sector.		Tax reform for innovative software (Colombia): exemption from the tax of rent for innovative software for a period of five years.	
	Malta Life Science Park: • knowledge cluster between the University of Malta, Malta's general hospital • physical space and infrastructure where pharmaceutical research companies can grow and foster.	QuTech (Netherlands): Dutch institute for quantum technology.	QuTech (Netherlands): Dutch institute for quantum technology.	
	Business support system (Poland) that provides comprehensive assistance to entities conducting R&D in industry in the area of advanced technologies known as "key enabling technologies."	Business support system (Poland) that provides comprehensive assistance to entities conducting R&D in industry in the area of advanced technologies known as "key enabling technologies."		Business support system (Poland) that provides comprehensive assistance to entities conducting R&D in industry in the area of advanced technologies known as "key enabling technologies."

Note: Policy descriptions have been truncated. An individual policy may be both “technology-push” and “application-pull”, and may be assigned to more than one technology field.

Source: 1. 2008 “Inventory of National Science, Technology and Innovation Policies for Nanotechnology” (nanotechnology only) (OECD, 2009_[11]). 2. 2014 “EC (European Commission)/OECD International Survey and Database on Science, Technology and Innovation, edition 2014” (Section D: biotechnology (D1), nanotechnology (D2), ICTs (D3)) (EC/OECD, 2014_[12]). 3. 2016 “EC (European Commission)/OECD International Survey and Database on Science, Technology and Innovation, edition 2016” (Section D: biotechnology (D1-1), nanotechnology (D1-2), ICTs (D1-3)) (EC/OECD, 2016_[12]). 4. 2016/2017 “BNCT-STIP Survey: International Survey on STI Policies for the Development of an ‘Inventory of Science, Technology and Innovation Policies of for BNCT’” (biotechnology, nanotechnology and converging technologies) (OECD, 2016_[13]).

Notes

¹ Note: The type and description of policies in the area of ICTs poses some difficulties to unambiguously categorise policies between “technology push” (i.e. broad policies for digitalisation/ICTs) and “application-pull” (i.e. policies focussed on broadband expansion, or policies enhancing SME access to ICT services); in cases of doubt, policies were categorised to be both “technology-push” and “application-pull”.

² Foreign application-pull policies (i.e. country-level spill-overs), can be observed, when domestic innovation is triggered by foreign policies (and *vice versa*) (Peters et al., 2012_[8]). According to an in-depth analysis, such effects are not to be underestimated, and are subject to heated discussions in the light of public “lead market” initiatives (OECD, 2011_[4]) (Peters et al., 2012_[8]).

³ The specific instruments stipulated by policies are also often referred to as “support types” and “policy modalities” (OECD, 2011_[19]): the instruments are often non-exclusive with the same instrument being employed for several purposes, while the modality of an instrument describes the means or specifications used to operationalise/implement an instrument (Jacob, 2013_[20]).

⁴ It needs to be noted that the policy instrument is not always stipulated in the survey questionnaire responses; at the same time, one policy may list up to three different instruments.

⁵ The (English) terminology used by countries and regions to refer to and describe their relevant plans and principles pertaining to reaching of socio-economic targets may vary widely between “policy”, “strategy”, “action plan” and descriptions of initiatives and activities. For the sake of simplicity, all such initiatives entered and described by countries or regions under the relevant sections of the surveys are referred to as “policies”.