HIGHER EDUCATION, RESEARCH AND INNOVATION IN PORTUGAL

PERSPECTIVES FOR 2030

Higher Education, Research and Innovation in Portugal

Perspectives for 2030

Preface

Three main targets are considered for Portugal to fully achieve European convergence by 2030 and to boost knowledge and innovation, together with skilled job creation and wellbeing. They include:

1. Achieve a level of **overall R&D investment of 3% by 2030**, with a relative share of 1/3 public and 2/3 business expenditure, corresponding to achieve an overall R&D investment of 1.8% of GDP by 2020 (while 1.3% in 2016);
2. Achieve a level of **40% of tertiary education graduates in the 30-34 years old age group by 2020** (while only 35% in 2016), and **50% by 2030**, with **60% of those aged 20 participating in higher education by 2030**;
3. Achieve an European **leadership level of digital skills by 2030** in association with internet access and usage, as well as market demand, business development and specialized skills development.

Setting a clear strategy towards these targets is important because Portugal, as well as other southern and peripheral European countries, have started in 2016 to recover from the recession and economic and budgetary problems that seriously affected the country in the period 2010-2015, with a major impact in the budgets allocated to S&T and higher education. This has occurred after three to four decades of a serious attempt to reduce the knowledge gap in terms of an effective presence in "scientific Europe", with significant results, although still far beyond the status of developed regions in central and northern European regions.

This strategy results from the OECD review to Portugal developed during 2016-2017, which facilitated and promoted a detailed analysis and discussion of Portugal's research and higher education systems, together with a process of serious public engagement in the discussion of the OECD recommendations to further strengthening the country´s performance in terms of an international perspective and multidisciplinary approach. This process has occurred about ten years after a previous OECD review of the Portuguese tertiary education system, in 2007, which resulted in a major reform of tertiary education and the development of a new legal framework for higher education, as approved by Parliament in 2007.

In the last 30 years, the internationally recognized scientific production of Portugal multiplied by more than 35 times (in terms of number of publications registered in the Web of Science), the number of patents registered in Europe increases about 50 times and the technological balances of payments balances up since 2007.

The number of PhD holders per thousand inhabitants more than doubled. The education system was modernized, although only in 2012 the proportion of PhD staff in the faculty of public universities exceeded 70%. About 42% of all 20 years-old young people attend higher education now. All these changes occurred along a significant increase in the Gross Expenditure in R&D (GERD) from 0.5% of GDP in 2000 to over 1.5% in 2010. In Europe, only Estonia, Luxembourg and Slovenia increased their R&D expenditure at a similar rate during this period.

However, this reform was interrupted in 2011, when the social and political commitment to science was, above all, broken by the political will to finance only 'excellence' and increase selectivity on the access to science, together with dramatic changes in research assessment procedures. This was indeed a dangerously close view to all that prevented Portugal from taking on the challenge of early science before the 70s. There is no scientific system that is sustainable if based only on a limited and exclusive group of scientists.

In this context, our main goal is to guarantee the convergent path with Europe re-initiated in 2016 and to launch initiatives to ensure a stable commitment to the production and application of scientific knowledge as a main driver for the development of the country and the building-up of networks of opportunity.

Important challenges remain in terms of education, training and qualification of the Portuguese citizens. The structural deficit on skills (55% of adults aged 25-64 years did not complete upper secondary education and about 45% of the workforce have few or no digital skills) and the level of retention among young people limit the economy's potential for innovation and competitiveness and creates inequalities in the population income and in the labour market. Portugal is one of the OECD countries with a lower percentage of higher education graduates in the population aged 25-64 (29th place in 34 countries), which has an obvious impact on the competitiveness of our economy and justifies the efforts to increase the qualification also in the higher levels of education.

It's now time to work to fully achieve European convergence by 2030 and to boost knowledge and innovation, together with skilled job creation and wellbeing.

Manuel Heitor

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A. Main targets towards European convergence

Three main targets are considered for Portugal to fully achieve European convergence by 2030 and to boost knowledge and innovation, together with skilled job creation and wellbeing. They include:

4. Achieve a level of **overall R&D investment** of 3% by 2030, with a relative share of 1/3 public and 2/3 business expenditure, corresponding to achieve an overall R&D investment of 1.8% of GDP by 2020 (while 1.3% in 2016);
5. Achieve a level of 40% of **tertiary education graduates** in the 30-34 years old age group by 2020 (while only 35% in 2016), and 50% by 2030, with 60% of those aged 20 participating in higher education by 2030;
6. Achieve an European leadership level of **digital skills** by 2030 in association with internet access and usage, as well as market demand, business development and specialized skills development.

1. Gross expenditure in R&D (GERD)

The recent publication of the official R&D statistics for 2016 show an increase in the overall R&D investment to 1,3% of GDP and, at last, the inversion of the continuous relative decrease in public and private expenditure in R&D since 2010. The data shows a few remarkable signs, namely:

- The **increased spending on R&D is particularly significant in the private sector**, which increases by 8% (i.e., 90 million Euros) between 2015 and 2016 and accounts for about **half of national expenditure on R&D**;
- R&D spending in the higher education sector grows by about 4% (i.e., 42 M €) to 1.059 MEuros, still accounting for about 0.57% of GDP. **Together with the Government sector, they represent 0.64% of GDP**.
- The **number of researchers grows in the private sector and in higher education about 6% between 2015 and 2016**. Higher education includes 26432 researchers ("full time equivalent", FTE), representing about 65% of the total, while the private sector includes 13041 researchers (FTE), representing 32% of the total.

Following the R&D statistics for 2016, a main desirable scenario is foreseen for the evolution of public and private expenditure in R&D to achieve a level of **overall R&D investment of 3% of GDP by 2030**, with a relative share of 1/3 public and 2/3 business expenditure. This requites:

- To **grow public R&D expenditure** at least about **90 million euros per year** in the period 2018-2030;
- To have **business R&D expenditure to grow** around **280 million euros per year** in the period 2018-2030.

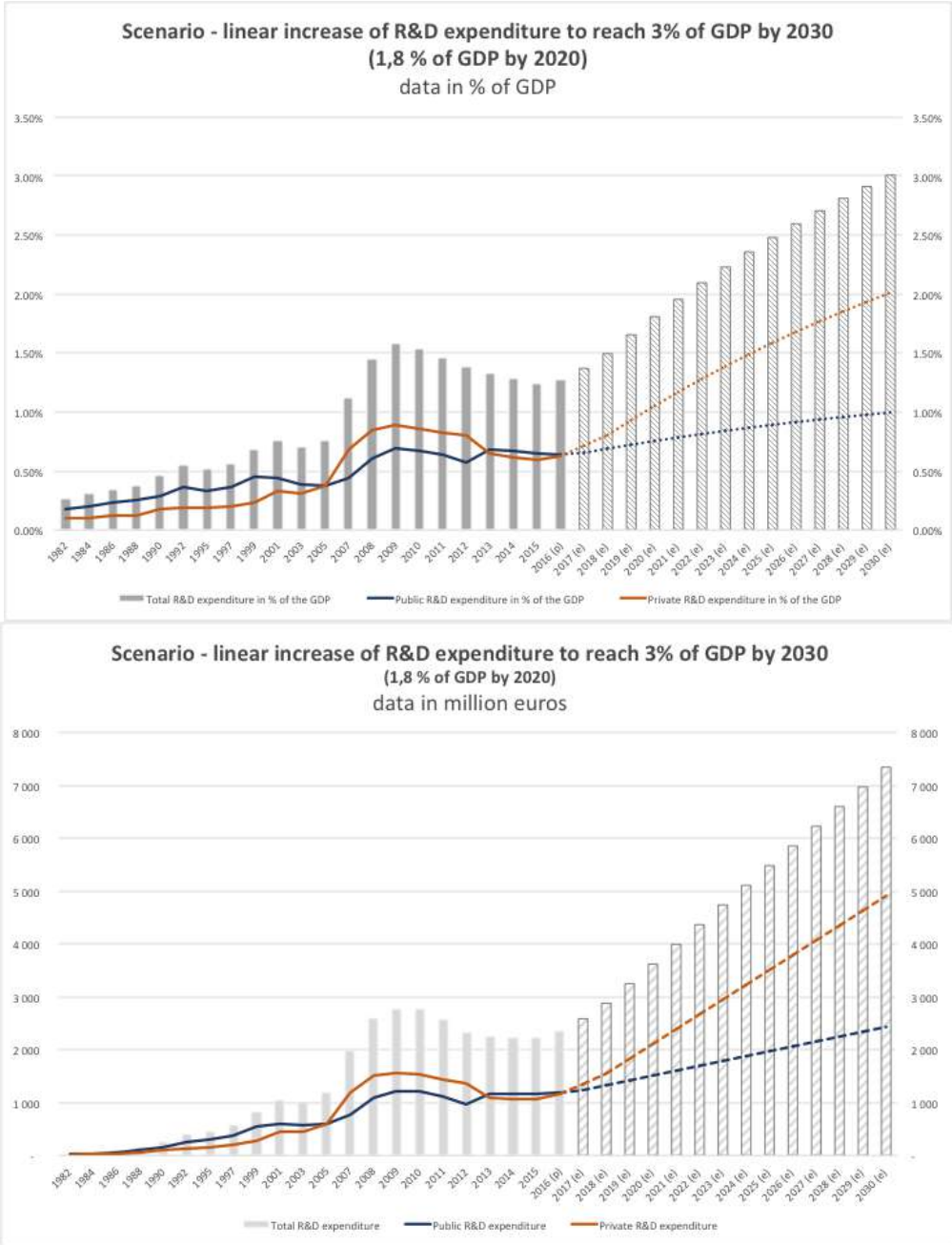
For comparison, public and private expenditure in R&D increased in 2016 about 23 and 90 million euros, respectively. By extending such growth rate of both public and private expenditure in R&D will allow to set the following targets:

1. Increasing private expenditure in R&D by 3,6 times between 2017 and 2030 (from about 1550 M€ to 4900 M€), which requires an yearly increase of about 2000 skilled jobs for researchers in the business sector during this period. Overall, requires creating about **25 thousand new jobs in the business research sector in the period 2018-2030**;
2. Double public expenditure in R&D between 2017 and 2030 (from about 1240 M€ to 2450 M€). This requires increasing per capita intensity of funding, together with an yearly increase of about 500 new doctorate research contracts in the higher education and government sectors during this period. Overall, requires creating about **6,5 thousand new doctorate research contracts until 2030** in the higher education and government sectors.

In addition, advanced training at doctoral level and scientific employment should evolve up to 2030 at the following annual growth rates:

- **Advanced training at doctoral level** should consider about **1750 new doctoral fellowships per year** (for comparison, 950 new doctoral fellowships were awarded in 2015 and 1230 in 2016; with current forecast of 1440 in 2017; 1664 in 2018; and 1750 from 2019);
- **Scientific employment** should continuously grow at a yearly level of about **500 new doctorate research contracts awarded through public funding** and about **2500 new doctorate research contracts awarded through private funding**.

Figure 1.1.
Scenarios of increase in R&D Expenditure



In other words, the forecast presented above requires a public and private effort to change the specialization profile of the national economy and to grow a knowledge-based economy. The analysis suggests three main orientations regarding the need to increase public and private R&D expenditure, namely:

1. Ensure a **continued growth in public R&D expenditure of, at least, 90 M€ per year** through supports for science, technology and higher education, in particular with more qualified human resources. It requires strengthening the employment of qualified teachers and researchers in universities, polytechnics and our scientific institutions.
2. Foster **fiscal incentives for R&D** and strengthen their role to stimulate doctorate employment by the business sector, in order to guarantee a continuous **growth in business expenditure in R&D of about 280M€ per year, together with skilled job creation**;
3. Invest in "Intermediaries" in Portugal, namely in "**Collaborative Laboratories**", to stimulate ways of **"risk sharing" to leverage private investment and guarantee increasing qualified employment**. This will help to change the structure of the economy and to access competitive and sophisticated markets around the

world. Existing technology centres should grow and be developed in collaboration with science and stimulate many other "collaborative laboratories" between business, science and higher education. This goal has been framed under the “Interface Program", which aims to make a new reality in Portugal from 2018.

The ability to grow private R&D expenditure is real and effective. It implies growing the qualified labor market in Portugal through accessing demanding markets and increase exports to sophisticated world markets. Ultimately, it requires to grow public R&D expenditure and training more specialized and qualified human resources, by strengthening R&D in higher education.

The data for 2016 shows that there are sectors with a progressive growth in R & D, that still are below the values of 2010 but having strong growth potential combined with the internationalization of the economy (e.g., Telecommunications, Pharma, Energy, Services and Engineering). On the other hand, there is a relatively stable level of investment in R&D in some areas such as ICT or banking, where new growth opportunities arise in areas such as artificial intelligence or cybersecurity and mainly directed to foreign markets. Finally, the data shows some sectors in which R&D investment levels are not very significant (Health, Agro industrial, Space and Defense, among others) despite real growth opportunities and social and market needs. In general, a comparative analysis of 2016 data shows the following:

- **Telecommunications:** data from 2016 shows an increase in telecom R&D expenditure, but still with values far away from those of 2010. The potential for growth is enormous, including through suppliers of equipment for international markets .
- **arma:** the 2016 data shows a significant increase in pharmaceutical R&D expenditure. It should be one of the sectors with highest increase in R&D expenditure in the near future, provided companies operate in international markets.
- **Energy:** the data for 2016 shows a continuous very low level of R&D expenditure by energy companies. Their growth opportunity is huge because it the current low technological intensity in international relative terms.
- **Industry:** the 2016 data shows a growth path of &D in many companies, mainly in molds, especially those for exports. It should be one of the sectors to grow in R&D in relation with the emergence of "industry 4.0" and related industrial digitalization trends.
- **Agro Industrial:** the 2016 data shows that most domestic companies continue with very low levels of R&D expenditure. It should be one of the sectors to grow in the future, particularly to facilitate access to external markets.
- **ICT:** the 2016 data shows a relative maintenance of R&D levels, but the growth opportunities in this sector are real and very realistic, especially in new areas of artificial intelligence. It requires the a new development path towards high value-added services and sophisticated solutions, especially for accessing external markets.
- **Health:** 2016 data continue to exhibit low levels of business R&D expenditure. Growth opportunities in this sector are real and very realistic, especially with the growth of clinical trials and the growing need to invest in clinical research and products of personalized medicine.
- **Banking:** the 2016 data shows a relative maintenance of R&D levels, but the growth opportunities in this sector are real and very realistic, particularly in access to new financial markets.
- **Engineering:** the 2016 data shows an excellent development of the most modern engineering centres acting in Portugal, with a very significant increase in R&D expenditure, especially those with access to external markets. The recent development of these centres is the central goal of the INTERFACE program and especially the "collaborative laboratories" to be promoted in 2018.

In short, the capacity to grow business expenditure in R&D is real and effective, but requires a clear strategy to enhance innovation. It involves growing the skilled labor market in Portugal through access to competitive markets and increasing exports. In turn, it requires keeping a minimum growth in public R&D expenditure and to train specialized human resources. And this requires doing more R&D in higher education.

2 **Tertiary education attainment**

Convergence with Europe in 2030 requires Portuguese society to achieve a level of **40% of tertiary education graduates in the 30-34 years old age group by 2020** (while only 35% in 2016), and **50% by 2030**, with **60% of those aged 20 participating in higher education by 2030**.

Achieving the target of 40% of tertiary education graduates in the 30-34 years old age group by 2020 requires attracting for tertiary education between 26000 to 34 000 students aged today between 28 and 32 years old. It requires training, above current graduation levels, about 6000 new youngsters per year between 28 and 32 years old. This must be achieved by effective stimulus to foster the enrolment on short courses (i.e., Higher Education Professional Technical Courses, "TESP") by students above 28 years old. It also demands reinforcing digital skills.

Table 1.1
Portuguese tertiary education attainment, 2011-2016

Year	Resident population aged 30 to 34 years (in thousands)	EU2020 Target	Tertiary graduates in the resident population aged 30 to 34 years
2011	749 131	26,7%	200 018
2012	716 270	27,8%	199 123
2013	690 773	30,0%	207 232
2014	668 652	31,3%	209 288
2015	641 354	31,9%	204 592
2016	627 433	34,6%	217 092

Source: INE

It should be noted that a significant structural deficit persist in the Portuguese population: 55% of adults aged 25-64 have not completed secondary education, about 45% of the workforce has few or no digital skills and only 26% of the employed population have a tertiary education qualification. It should be noted that:

- The population cohort 30-34 years old in 2030 will be around 500,000 residents, based on the population projections of those aged 15-19 in 2015;
- In 2016, the level of 20 years old students in higher education was 42% of the same age cohort and the number of new students enrolled for their first graduation (including TESPs), is around 70,000 students (it will be 73.000 in 2017/18).
- Achieving about 60% of those aged 20 participating in higher education in 2030 **requires keeping opening-up higher education, particularly to guarantee that at least 70% of those students concluding secondary education via professional education access to higher education** (while only 13% in 2015);
- Achieving about 250.000 graduates in 2030 in the age cohort 30-34 years old (i.e., 50% of those in the 30-34 years old) **requires improving current success rates in higher education between 15% and 20%.**

It is in this context that the goal of achieving 50% of tertiary education graduates in the 30-34 years old age group by 2030, together with 60% of those aged 20 participating in higher education should become a major target for the Portuguese society. The challenge includes five main targets, as follows:

1. **Reduce early drop-out rates in basic and secondary education**, particularly for those with 15-17 years old;
2. **Enlarge access to higher education**, in particular by promoting access to higher education of those youngsters concluding secondary education through professional programs. This requires to continue promoting **short cycles for initial training** through **polytechnics (i.e., "TESPs")**, with a focus for **those students concluding secondary education via professional programs;**
3. **Foster adult training**, namely through:
    a. **short cycles (i.e., "TESPs") for those adults with a secondary education degree**, mobilizing polytechnics in close and effective **cooperation with industry and the business sectors**, with a special focus on **digital skills**;

b. **professional and specialized masters**, mobilizing polytechnics and universities in close and effective **cooperation with industry and the business sectors**, with a special focus on **digital skills**;

4. Improve **success rates in higher education, in both universities and polytechnics;**
5. **Adequate and articulate immigration and education policies**, promoting Portugal through education and research, in particular strengthening the initiative "Study and Research in Portugal".

3. Improve Digital Skills

Creating a more resilient society involves developing new competences, including digital skills, which are constantly changing and evolving. At the same time, it involves preparing people for a growing uncertainty in markets and technology change, requiring people prepared to tackle jobs that will become very much different that those characterizing our current economic structure.

It is in this context that "Portugal INCoDe.2030 – the national initiative to foster digital skills" includes integrated actions aiming to stimulate and guarantee the development of competences as tools to help prepare the new generations for the "unknown", investing increasingly in new knowledge and in the capacity to create new jobs - more qualified and better paid - encouraging entrepreneurial attitudes in young people.

The Portugal INCoDe.2030 initiative addresses the concept of digital competences in a broad manner. It includes the notion of digital literacy (i.e. the ability to access digital media and ICTs, understand and critically assess contents, and communicate effectively), as well as the production of new knowledge through research, which involves processing information, and communicating, interacting with and producing digital content.

Table 1.2
Portugal INCoDe.2030 Goals

	Goals		
	2020	**2025**	**2030**
Broadband Acess			
% of households with access to the Internet	80%	90%	95%
% of individuals that never used the Internet	20%	10%	5%
% of individuals that frequently use the Internet	70%	80%	90%
Human Capital			
% of individuals with basic digital skills – or more than basic	65%	75%	90%
% of ICT specialists at employment	4%	6%	10%
STEM graduates for 1000 inhabitants (20-29 years)	22%	24%	26%
New PhD per year for 1000 inhabitants (25-34 years)	2,6	2,8	3
Use of Internet			
% of employees that use computers with Internet connection at work	50%	70%	90%
% of SME with High Level of Digital Intensity	20%	30%	40%
% of individuals that used the internet for banking access (last 3 months)	50%	75%	90%
% of individuals that used Internet for interaction with online public services (last 12 months)	60%	75%	90%
R&D Investment			
GERD - Gross Expenditure in R&D	1,6	2	2,5
BERD - Business Expenditure in R&D	1	1,5	2

The concept of digital competences is also linked to the use of digital technologies to design new solutions for different types of problems, the integration of interdisciplinary knowledge and data analysis, intensive use of artificial intelligence, the use of advanced instrumentation and communication networks and mobile systems, and the development and programming of cyber-physical systems. This involves hardware and software and extends the concept of ICT to electronics, automation and robotics.

Competences can be developed to different levels of depth and proficiency in each of these areas, depending on the level of qualification and set goals. These different levels are reflected in the type of measures that will be promoted in an inclusive and comprehensive way for the whole of society.

The aim of the National Digital Competences Initiative, Portugal INCoDe.2030, is to position Portugal at the top of European digital competences ranking by overcoming three big challenges:

1. Generalise digital literacy, with a view to the full exercise of citizenship and inclusion in a society with increasingly more digital practices, where many social interactions happen on the internet and are increasingly mediated by electronic devices.
2. Stimulate employability and professional training and specialisation in digital technologies and applications, in order to respond to the increasing demand of the market and to promote the qualifications needed for employment in a higher value-added economy.
3. Ensure strong participation in international R&D networks and the production of new knowledge in digital areas.

B. Portugal commitment to science and knowledge: *the process*

The strategy for Portugal achieving European convergence by 2030 enlightens new insights in science, technology and innovation policy. It faces main challenges and opportunities for policy making in order to better integrating education, research and innovation activities of higher education institutions (HEIs) and public research institutions (PRIs) to foster greater synergies and impacts from public investments in education and research at the local and global levels. Ultimately, it clarifies the increasing complexity of policies to foster private and public incentives to support R&D, strengthening the investment in research and education through the advanced qualification and employment of skilled human resources, together with adequate institutional and international relational frameworks, through a diversified set of lines of action.

In institutional terms, the goal is to foster **scientific and qualified employment** and to attract skilled human resources to Portugal in all areas of knowledge, together with **risk-sharing partnerships** among government, industry and academia oriented towards skilled employment and wealth creation. It is proposed that this is implemented in close association with the increasingly relevant role played by intermediaries and the new initiative launched in Portugal to foster ***Collaborative Laboratories***.

In addition, it helps creating new specialized initiatives to foster new frontiers of knowledge and innovation in critical and emerging areas aiming to position Portugal in a new stage of maturity in an increasingly globalized knowledge-based economy. This includes, among others, the promotion of a **human-centered science and innovation policies**, together new **R&D agendas** on specialized topics taking into account the unique geographical location of Portugal in-between the Atlantic and Mediterranean areas, as well as the adequate valorization of existing scientific capacity. Prioritizing agendas on Atlantic interactions, Space, sustainable agriculture innovation and clinical and biomedical research, among other areas and together with science-based entrepreneurship, are planned as follows:

- A new international R&D and innovation agenda, "***Atlantic Interactions***", encompassing new technology businesses and ventures, to be promoted through the creation of the "***Atlantic International Research Center*** **AIR Center**", in the form of an intergovernmental organization to be created through a Public-Private partnership of international nature, together with a new Space R&D and innovation agenda, "**Portugal Space 2030**", encompassing new technology businesses for "New Space";

- A new international R&D and innovation agenda focused on the **sustainable management of water and energy provision and food systems in the Mediterranean area**, as aligned with the European initiative PRIMA – *Partnerships on Research and Innovations in the Mediterranean Area*. Climate change is increasingly causing severe water shortages in the area, with major impacts on agriculture. Most water available is used for irrigation. This means that such shortages result in decreasing and irregular crop yields, putting additional pressure on natural resources and on the capacity to provide clean water and affordable food for the region's inhabitants. This in turn has a negative effect on nutrition, health, livelihoods, standards of living and levels of wellbeing.

- A new **clinical and translational health and biomedical research and innovation agenda** in a broad set of areas with clear impact on the quality of life, including the promotion of medical physics and cancer research with specific applications for the health sector, to be promoted through "Clinical Academic Centers" and the creation of a new "Clinical Research and Biomedical Innovation Agency" involving a public-private partnership, encompassing the promotion of clinical research and new technology businesses;

- Strengthening **digital skills and processes of digital transformation**, including digital design and manufacturing. Research includes multiple aspects of the digital transformation that is enabling new integrated approaches for adaptive design, manufacturing and sustainable solutions. Projects can investigate new practices in the generation and development of cyber-physical products, assuring improved user experience and value creation for society and the economy. In this context, strategies for designing at the *speed of thought* should be developed, for example, to design, manufacture and launch revolutionary wafer satellites and microSat constellations focused on land and ocean use, animal migration, algae blooms, top soil erosion, and regenerative agriculture. Research involves various aspects of urban science, design, and

engineering with applications in areas such as energy utilization, air quality maintenance, transportation systems, internet-of-things connectivity, and smart cities.

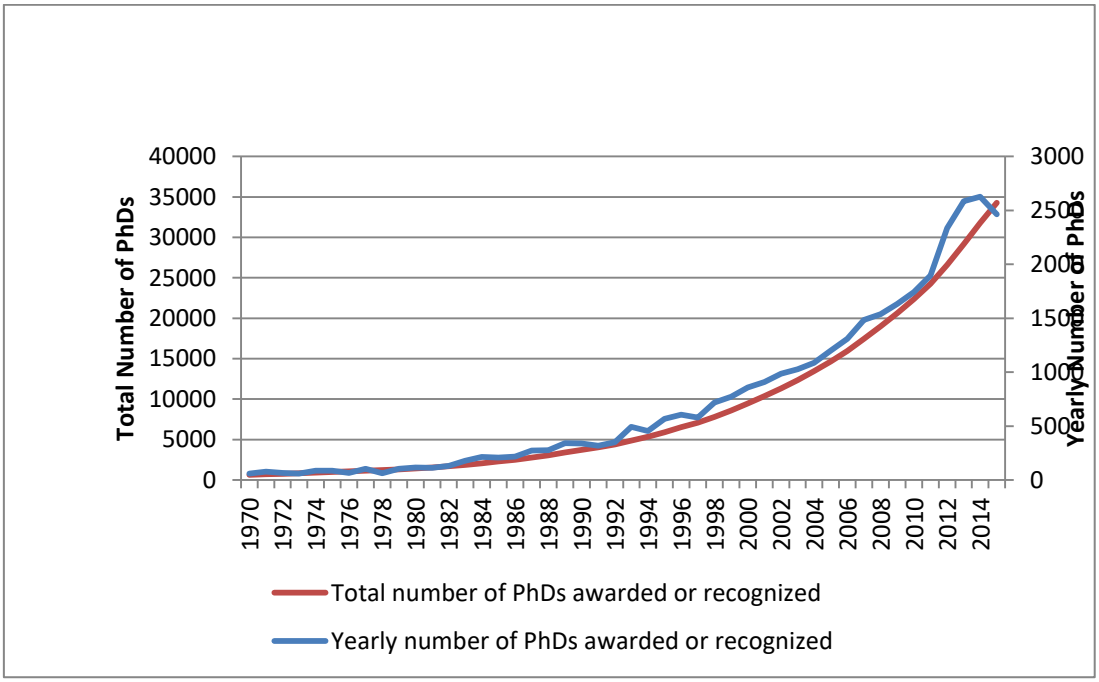
These areas require a new cycle of **international partnerships in research and academia**, involving universities and polytechnics, as well as promoting science based entrepreneurship to foster the creation and development of new technology businesses. This will be promoted through the initiative "**Global S&T Partnerships Portugal - GoPortugal**", as described in this report.

1. A program to stimulate scientific employment in Portugal, 2017-2030.

The goal is to enlarge public and private expenditure to promote 5000 new doctorate contracts in academic, research and business organizations until the end of 2019 and to continue a sustainable growth strategy for scientific employment towards European convergence in 2030.

During the last four decades Portugal has made a remarkable investment in the education of advanced human resources in science and technology and the Figure below shows that the number of PhD holders in Portugal has increased almost four-fold since the beginning of the century, although with a reduction in the period 2013-2015. With about 2500 new PhDs per year, the Portuguese system has been able to reach over 35.000 PhDs awarded or recognized in Portugal.

Figure 1.2
Total number PhD degrees awarded in Portugal and the flow of new yearly PhDs, 1970-2015.



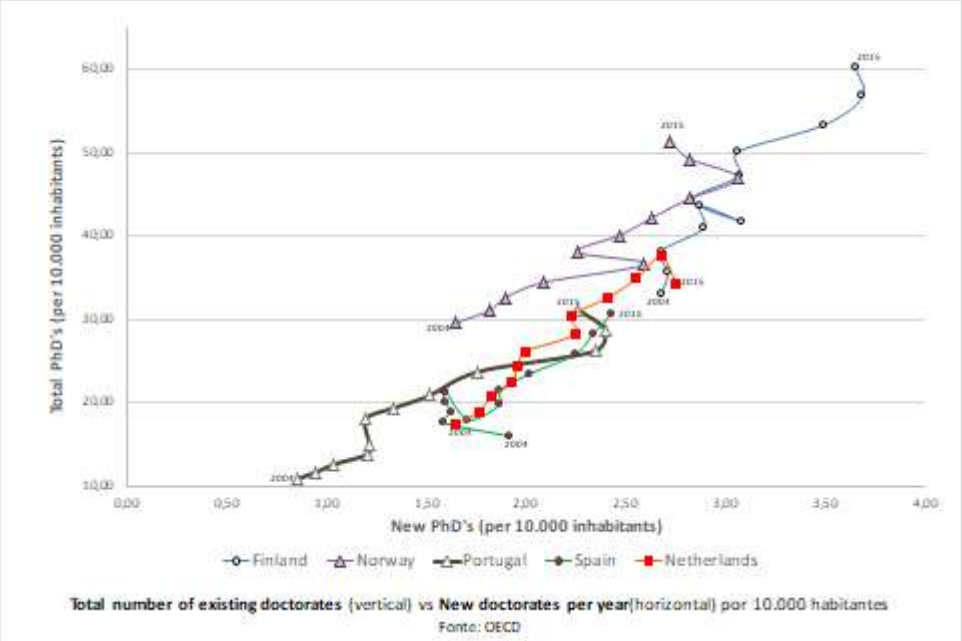
Source: DGEEC

Analysis shows:

- The significant investment in advanced education of human resources in Portugal over the last thirty years has represented a strong upgrade of the research and innovation system, largely led by public investment. The PhD scholarships supported by the Foundation for Science and Technology (FCT) have reached a maximum of about two thousand new individual scholarships in 2007, although with a significant reduction in following years, with a minimum number of only 685 new scholarships in 2013. This trend has been recovered in recent years, with over 1440 new PhD scholarships supported in 2017. The goal is to stabilize in the coming years the public support of PhD scholarships in about 1600 to 1800 new scholarships per year.
- The figure below expands the information presented above and quantifies the *stock* (i.e., full amount of PhDs with Portuguese residence) versus the *flow* of new yearly PhDs for Portugal in comparison with other European countries. The trend-lines exhibit a quite different path in the countries considered, with Portugal and Spain following the Dutch pattern, but quite different from the situation in Finland. In the case of Portugal, it is also important to note that the path is almost linear because the growth rate of the stock does not match what would be expected by the two-fold increase in the flow of new doctorate holders since 2000. A possible reason for this is that a significant portion of newly-graduated doctorates had not actually remain in the country, creating an additional challenge for Portugal in terms of the emergence of a new era of brain drain.

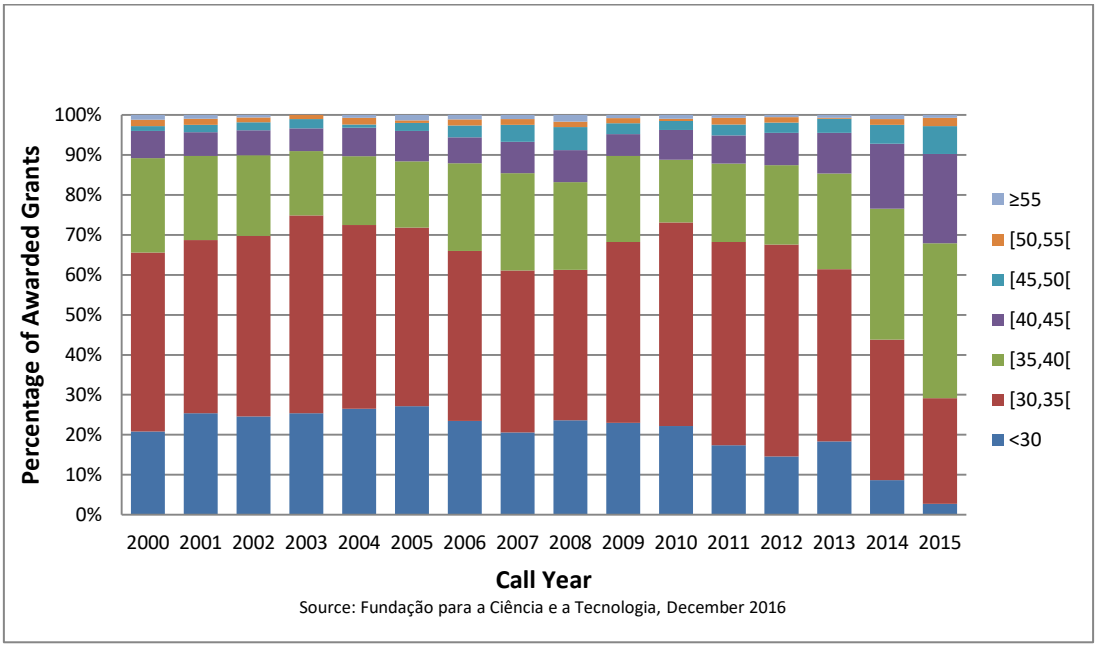
Figure 1.3

Stock versus Flow of doctorates holders for 2004-2015, as quantified in terms of the total number of PhD's (vertical) and the yearly number of new PhD's (horizontal) by 10.000 inhabitants.



- The data above clearly contradicts recent arguments in many European countries and world regions that there are "too many PhDs" and argues that there is a need to understand better the changing nature of doctorates and doctorate holders. Portugal is still lagging behind most European countries in both the stock and the flow of new PhDs, with the overall fraction of doctorate holders in the faculties of public universities still as low as 70%. In addition, human resources in science and technology are currently at 6,5% of active population, still below the average of 6,8% in the EU (but this difference was much more significant in 2000, with 2,3% in Portugal vs. 4,1% in the EU).
- In complement to doctorate scholarships, FCT has supported research career trajectories through a number of schemes, either indirectly, through project grants that lead to research opportunities for PhD holders, or directly, through dedicated funding schemes to support post-doctoral engagement in R&D activities. The post-doctoral scholarships program has supported on average 500 post-docs per year, since 2000, through highly competitive calls. Since 2007 new instruments to support scientific employment emerged in the form of doctoral research contracts directly supported by FCT, to follow-up on post-doctoral scholarships. However, these have not kept pace with the need to support a greater number of PhDs in the research system, to guarantee appropriate critical mass. The number of doctoral research contracts supported by FCT has reached a maximum value of 1200 contacts in 2010, with only 660 contracts in 2015 and 2016.
- It should be noted that the post-doctoral scholarships were envisaged as a temporary scheme, providing a follow-up to the PhD degree to consolidate post-doctor al training, but they became a central instrument to hire doctoral researchers, widely used in the system, in view of the reduced emergence of employment opportunities across the different sectors.
- The figure below quantifies this trend through the evolution of the age structure of post-doctoral scholars funded by FCT. While in 2000 65% of new post-doctorate holders were aged under 35, with 21% aged under 30, in 2015 only 29% were aged below 35 and over 30% were 40 years old or older. The figures also reflect the intense competition for new positions, with a significant stock of highly qualified researchers applying for open positions. Overall, the data reflects the conditions which doctorate holder's face, largely missing an adequate contractual basis at an age where relative work stability is important for the development of in-depth research activities.

Figure 1.4
Evolution of the age structure of post-doctoral scholars funded by FCT, 2000-2015



Source: FCT

- In view of the lack of appropriate contracting opportunities and the existence of a very rich critical mass of doctorate holders, the system has had difficulties in retaining some of the best young researchers, with a considerable number of young researchers opting to emigrate. This is reflected, for example, in the fact that while public higher education institutions in 2001 employed 42% of academic staff with an age below 40 years old (and 25% with 50 years old or older), in 2015 this distribution had totally inverted, with only 21% of academic staff below 40 years old (and 47% of academic staff with more than 50 years old). The need to provide conditions to support adequate new contractual arrangements for young staff to access career development in research and academia is evident.

The action: **a new program to foster scientific employment and access to research careers**

The analysis above motivates a stimulus action to foster scientific employment in Portugal, serving the dual objective of fixing talent in Portugal, while invigorating the scientific community and be used to help renewing the academic and research systems. The Program has been designed to consider the following terms of reference:

- To include a set of diversified and distinct incentives and competitive open bids;
- To promote institutional co-responsibility, by bringing together public funding together with institutional initiatives to co-fund the employment of doctorate holders.
- To foster the attractiveness of Portugal to retain talent, guaranteeing competition under strong international standards, and to promote young researchers to research institutions
- To promote frontier research and innovation in terms of sources of ideas and value to the economy and society at large.

The overall Program includes the following 8 lines of action for the period 2017-2019 (3 years of investment), covering a total of 5000 expected research doctorate contracts to be awarded:

1. Individual doctorate research contracts in research and academic institutions:
    - Public open competitions to be offered through FCT for individual doctorates;
    - Contracts fully supported by FCT for periods between 3 and 6 years;
    - Three annual competitions in the short term: 2017, 2018 and 2019; to be continued annualy.

2. Institutional employment and research career development plans:

- Public open competitions to be offered through FCT for institutions;
- Contracts partly supported by FCT, between 30% and 50%, of total cost, for periods between 3 and 6 years;
- Two annual competitions in the short term: 2018 and 2019;

3. Institutional recruitment and career development plans:

- Public open competitions to be offered directly through the institutions;
- Contracts fully supported by institutions;

4. Individual doctorate research contracts through FCT funded R&D projects:

- Public open competitions to be offered through FCT for R&D projects, with the need to offer a doctorate research contract;
- Contracts fully supported by FCT for periods of up to 3 years;
- Bi-annual competitions, from 2017.

5. Individual doctorate research contracts in research and academic institutions to be funded by FCT through the transition regime for the new legal regime of scientific employment (DL 57/2016):

- Public open competitions to be offered through institutions for individual doctorates;
- Contracts fully supported by FCT for periods between 3 and 6 years;

6. Individual doctorate research contracts through Collaborative Laboratories:

- Public open competitions to be offered through FCT and PT2020 for establishing Collaborative Laboratories, with the opportunity to offer doctorate research contracts;

7. Individual doctorate research contracts through European co-funding mechanism:

- Public open competitions at EU level, including “Marie Curie Fellowships”;
- Annual competitions;

8. Fiscal incentives for the employment of doctorate researchers by the business sector (i.e., SIFIDE):

- Recruitment and career development paths offered directly through business firms;
- Contracts fully supported by business firms, with fiscal incentives;

2. Collaborative Laboratories and other risk-sharing partnerships among government, industry and academia oriented towards skilled employment and wealth creation, 2017-2030.

Collaborative Laboratories, CoLABs, aim to stimulate qualified employment and knowledge-based economic growth in Portugal, complementing and reinforcing the current structure and performance of R & D units and associated laboratories. They aim to stimulate the active participation of the scientific and academic system in the understanding and resolution of complex and large-scale problems which are generally not capable of being solved within a single disciplinary, scientific, technological or institutional strand. In addition, they involve the coordination of different scales and a business, social and cultural intervention with a view to the implementation of effective solutions and with socio-economic impact.

In this context, the development and promotion of Collaborative Laboratories has been stimulated since 2017 within the framework of mobilizing agendas and research and innovation programs, duly agreed between universities, polytechnics, R&D units and associated laboratories, State laboratories, and social, cultural and economic fabric, including enterprises, intermediary institutions and knowledge transfer, including technological and engineering centers, in order to establish an effective 'Commitment to Knowledge and Science' which stimulates technological change and the creation of economic and social value.

The agendas should be the result of a joint and collaborative effort between researchers from public and private sectors, adopting a matrix that crosses priorities of specialization with technologies and scientific knowledge of a transversal nature and defining a reference for the allocation of the financing of public policies for science and Innovation. The aim is to mobilize the productive, social and cultural sectors in order to facilitate and reinforce the qualification of the population at the local level, stimulating qualified employment and converging towards the European average in terms of the public and private R & D investment effort.

The role to be played by Collaborative Laboratories will be especially important in order to eliminate the gap between research and innovation activities, improving the value of products and services provided by companies. Their establishment in Portugal represents a new phase of evolution and development of the scientific and technological system to reinforce the institutionalization of the collaboration between different institutions, together with the interinstitutional co-responsibility of knowledge based strategies, as well as the reinforcement of the collaboration of institutions scientific and higher education institutions with a number of “technology centers” and other intermediary institutions promoted in the last 30 years.

In this context, Collaborative Laboratories should be understood as the reinforcement of existing intermediation institutions, including technological interface centers, as well as the creation of new institutions, as a result of collaboration between research units, associated laboratories, higher education institutions, intermediate and interface institutions, technological centers, companies, business associations and other relevant partners in the productive, social or cultural fabric, such as state laboratories, local authorities and institutions associated with local organizations, hospitals, museums, archives, or social, national or international institutions).

The main challenge that the Collaborative Laboratories must respond to is the effective densification of the national territory in terms of knowledge-based activities, through a growing institutionalization of forms of collaboration between institutions of science, technology and higher education and the economic and social fabric, including business, the hospital and health system, cultural institutions and social organizations.

Collaborative Laboratories should thus consolidate and promote the capacity and potential that the scientific and academic communities present to face the opportunity to relate knowledge with social and economic well-being and development in Portugal. It is the opportunity for scientific and academic institutions, in close collaboration with economic, social and cultural actors, to contribute to the construction, in Portugal, of projects of international relevance, with an effective impact on society.

Strategy and International references

Collaborative Laboratories complement the current scientific organization in Portugal, densifying the territory in activities based on knowledge. Unlike R&D units and Associate Laboratories, they must have a clear business plan and be designed to facilitate the attraction of new sources of funding, alternatives to the Foundation for Science and Technology (FCT). They may involve the creation of a new private institution, which can be affirmed in the Structural Funds and emerging private markets.

The future CoLAB network should be based on other international networks in Europe, including those built in the last decade:

- France - *Carnot Institutes, http://www.instituts-carnot.eu/en, with 38 institutes (29 institutes and 9 associated Inst institutes), since 2006;*
- UK - *Catapult Institutes, https://catapult.org.uk/catapult-centres/, also in: https://catapult.org.uk/about-us/key-documents/, with 11 institutes created since 2013;*
- Spain – IMDEA, http://www.imdea.org/presentation (Madrid Institutes of Applied Studies) in the great zone of Madrid, with 7 institutes created since 2007.

These institutions have been created and promoted on the basis of the oldest references in Germany and the Netherlands, which have been based on a scheme of public and private financing sharing, respectively: 1/3 public, 1/3 public competitive (National and European) and 1 / 3 private. The main example of these institutions include:

- The Netherlands - TNO, https://www.tno.nl/en/about-tno/locations/?q=&cat=&gsa_Country=The+Netherlands, with 23 centers in Holland since 1932 (85 years)
- Germany -*Fraunhofer Institutes, https://www.fraunhofer.de/en/about-fraunhofer/structure-organization.html,* with 69 institutes created in the last sixty years.

The program in action

The competitive selection of Collaborative Laboratories in Portugal was launched in the summer 2017 through the Portuguese Science and Technology Foundation, FCT, and making use of an high level international review panel. Initial public hearings were initiated in November 2017 and the first set of Laboratories were approved by January 2018, including the following six projects:

- **"Forest WISE" – Forest and fire prevention**
- **"Atlantic" – Space, climate and oceans**
- **"DTx" – Digital transformation**
- **"MORE" – Research and innovation in mountain regions**
- **"Wines and Vines" – wine and vines in the Douro region**
- **"Green CoLab" – Algae valorisation in Algarve**

In the meantime, an overall amount of about 30 million euros was approved by the Government to guarantee the basic funding of these Collaborative Laboratories for their initial five years of operation, 2018-2022, in a way to foster the recommendations of the international review panel and to guide their development path to attract national and international competitive funding, as well as complementary private sources of funding.

The program continues open to applications and other major initiatives are expected to be implemented in the course of the coming years.

3. Atlantic Interactions, the "Atlantic International Research Center (AIR Center)" and a new space strategy

Promoting a new international R&D and innovation agenda on "***Atlantic Interactions***" through the creation of the "***Atlantic International Research Center*** **AIR Center**", in the form of an intergovernmental, aims to provide a shared and international environment to support and foster new climate, earth, space, and marine research activities benefiting decision makers, public users, universities and industry as well contribute to retain highly skilled human resources and contribute to regional growth.

The AIR Center will consider a flexible international governance model with international statute and international legal status (i.e., emulating the CERN experience in Geneva or that of INL in Braga, Portugal, among others). It will provide a solid legal context to overcome potential national constraints as well as providing an appropriate regulatory framework to efficiently and effectively address operational issues such as staff regulations, financial contributions and definition of the several scientific programs.

The expected impact includes a new scientific and innovation platform at the best international level, offering a global-scale research site, capable of attracting scientists and technicians from around the world and can stimulate different forms of collaboration with other countries as well as public or private entities in a wide range of areas associated with research and education or commercial applications.

Background Information

Atlantic Interactions is a new research and innovation agenda to guarantee a reinforced commitment to knowledge through transatlantic and south-north/north-south cooperation. It has been established through multilateral cooperation in complex systems engineering and science towards an integrative approach to space, climate change and energy, earth and ocean science in the Atlantic, together with emerging methods of data science.

Figure 1.5
Island Research Stations across the world and the Azores archipelago location

The agenda is to be promoted through the:

i. installation of the "Atlantic International Research Center (AIR Center)", in the form of an intergovernmental organization to be created through public-private partnership of international nature;

ii. An international network of research and academic organizations across south and north Atlantic countries and in association with other scientific organizations worldwide;

iii. An international initiative on "Knowledge for space – space for knowledge", to promote education and scientific culture about space science and related opportunities, as well as to sue space technology for help promoting educational, cultural and scientific contents worldwide.

Goal and implementation

The goal is to provide a shared and international environment to support and foster new climate, earth, space, and marine research activities benefiting decision makers, public users, universities and industry, as well as to promote the employment of highly skilled human resources and contribute to growth. The ultimate goal is to stimulate the necessary knowledge-driven conditions to better use the strategic Atlantic positioning of Azores and Portugal to foster North-South cooperation in science and technology:

i. By promoting new knowledge on climate change and related issues in the Atlantic, we are fostering conditions to provide the world with more science, more knowledge and more scientific culture;

ii. By facilitating the access to space from the unique position of Azores, we are promoting access to new frontiers of knowledge, together with the development of new space industries;

iii. By promoting new research in the Azores´s deep-sea, we facilitate the access to a better understanding of living organisms in extreme environments and new energy sources;

iv. By stimulating the test of new renewable energy sources and their integration in smart networks in islands environments, we are promoting test beds for the development of new sustainable energy industries;

v. By facilitating new mega-sets of data on climate, atmospheric, ocean and energy related themes, we are stimulating new forms of data science and the development of new technology-based companies oriented towards big data processing and usage;

The preparation of the AIR Center has been centered under two main priorities: i) new data collection for innovative research; and ii) synergies Sea/Space towards new knowledge production, diffusion and technology commercialization.

The expected impact of the installation of AIR Center includes the development of a new scientific and innovation platform at the best international level, offering a global-scale research site, capable of attracting scientists and technology-based companies from around the world, as well as stimulating different forms of collaboration among European, North and South American, African and Asian public or private entities in a wide range of areas associated with research, education and technology-based businesses.

The scientific agenda for the AIR Center has been developed since June 2016 through an open debate and a series of workshops in Europe, USA, Latin America and Africa in a way that has shown that the need for a better understanding of the Atlantic Ocean and the sustainable management of this common resource require the alignment of research strategies through international cooperation. Interdisciplinary research able to face the ocean challenges and the economic transitions, in particular environmental changes, security conditions, and other human dimensions, almost by definition calls for the design of an international partnership that aims for resilience and scientific leadership in the Atlantic Ocean and related north-south cooperation in the following five thematic areas and related research challenges:

- **Atmospheric Science and Climate Change**:
- **Space science and technology:**
- **Ocean Science and Technology:**
- **Energy Systems:**
- **Data Science:**

The AIR CENTER aims to provide the following “potential” new and additional resources to those already existing at Azores:

- **Atmospheric Science and Climate Change**:
  - A new and unique north-south Atlantic observation platform through a network of six islands: Azores; Canarias, Cabo Verde; S. Pedro S Paulo and Fernando Noronha (Brasil); Bermudas;
  - A robust cyber-infrastructure for climate research;
  - Integration in the European and Global Research Infrastructure Landscape, namely: PICO-NARE; Global Atmospheric Watch; ACTRIS (Aerosols, Clouds, and Trace gases), IAGOS (In-Service Aircrat for a Global Obervating System), ICOS (Integrated non-CO2Greenhouse GAs Observing System) and InGOS;

    - Laboratory for detailed measurement of over 40 greenhouse gases, at high altitude (over 2000 m) at the Pico Island;
- **Space science and technology**:
    - Atlantic Spaceport for low cost access to Space;
    - Atlantic Surveillance Center;
    - NASA Space Geodesy project for Global Geodetic Observing System;
    - Space Surveillance and Tracking programme
    - ESA/NASA/Azores Launchpad Technology Incubation facility
- **Ocean Science and Technology**:
    - Land based facilities: laboratories, experimental stations and monitoring stations;
    - Remote platforms: vessels, satellites and underwater robots;
    - Deep sea and open ocean long term fixed point observatories;
    - Equipment: sensors, vehicles and sensors that can operate below 200m;
    - Secure and reinforce high skilled critical mass of researchers through international collaboration;
- **Energy Systems**:
    - Geothermal exploration on Terceira: "Central Geotérmica do Pico Alto";
    - Electric Vehicle Deployment Demonstration in an island environment;
    - Flexible, efficient and resilient storage systems;
    - Renewable energy technologies deployment demonstration in a confined environment;
    - Full scale smart grid management of full scale laboratory aiming at 100% renewable energy;
    - Integration of renewable energy with desalination technologies for simultaneously balancing the grid and providing freshwater;
    - Integration of renewable energy with hydrogen production (via electrolysis) or methane production (via methanation) for simultaneously balancing the grid and providing domestic fuels;
    - Ocean thermal energy conversion (OTEC), which uses temperature differences between the ocean surface and depths to generate electricity;
    - Osmotic power, which uses salinity gradients between freshwater onshore with saltwater offshore to generate electricity;
- **Data Science:**
    - A robust cyber-infrastructure, enabling tools, data sets, and computational models;
    - "Azores Maritime Cloud" as a technological platform and data hub responsible for providing: a portal, iAtlantic for open web access; Data correlation and fusion; Data storage and retrieval capabilities; Open interface; among other facilities;

There are already commitments from some European Member States, the US, Brazil and other countries for such endeavor, as co-founders. In this context, other countries have been invited to consider the possibility of joining this initiative and the creation of a new intergovernmental organization, in order to reinforce the leading role of Azores and the Atlantic in the framework of future north-south international cooperation in research and innovation.

To this effect, major international summits were organized in 2017, respectively in Terceira Island, in Azores, in April (20-22 April), and in Florianopolis, Brazil (20-21 November). In this context, the "Florianopolis Declaration" has created the AIR Center and defined a related installation committee. Next steps include:

i. **8-9 May 2018, Cabo Verde**: International Summit to assess the progress on the installation of the AIR Center and the agenda "Atlantic Interactions";

ii. **21 November 2018, Canary Islands**: International Summit to conclude the installation of the AIR Center and foster the agenda "Atlantic Interactions", as well as to define further steps and actions.

A Space R&D and innovation strategy and agenda for Portugal, "Portugal Space 2030"

The Portuguese leading role on the installation of the AIR Center and in development of the agenda "Atlantic Interactions" has been designed to be established in close relationship with a Space R&D and innovation strategy and agenda for Portugal, "Portugal Space 2030". It aims to help growing new space industries, together with space science and technology in Portugal, building up on the experience acquired after more than 15 years of Portuguese engaging in the European Space Agency, ESA. It should contribute to retain highly skilled human resources and contribute to promote new technology-based firms and skilled jobs.

This involves the future creation of the “Portuguese Space Agency”, through a flexible public private partnership and governance model will provide financial contributions to promote and expand the participation of Portugal in ESA and related international scientific programs in the area of new space industries.

The global demand for space systems is everywhere, although North American and European suppliers are still leading the world space markets. In particular the satellite manufacturing industry is in a growth cycle both from institutional and commercial entities. According to Euroconsult forecast, the 1,410 satellites expected to be launched until 2024 will potentially generate manufacturing revenues of $200 Billion, a growth of 22% compared to the period 2005-2014. Space is becoming an essential part of modern societies and private investments are growing every day. Space is effectively taking a new dimension with an increased number of countries and regions assuming space as a priority, together with the emergence of new commercialization models to explore space.

The new space movement, referred to as “New Space Industries”, is characterized by the need for seamless communication and information systems based on mega-constellations of micro- and nano- satellites and considering a diversity of objectives that are pushing the surging of a new private space industry in three main areas, which open new opportunities for Portugal, namely:

- Applications, based on specific software platforms dedicated to earth observation for economic activities, including managing urban development paths and procedures, agriculture (“precision farming”), fisheries (“precision fisheries”), forestry, and climate change, among many other activities;
- Satellite development and production, mainly micro- and Nano-satellites in the range 1kg-150kg, stimulating the use of digital industrial production methodologies and concepts that may be applied to large-scale satellite production from different sizes and configurations, enabling the development of mega-constellations, with expected developments announced for Low Earth Orbit (LEO) for broadband internet, earth imaging, meteorological data and other applications.
- Launching systems, facilitating to reduce the cost to access space, through small launchers, new propulsion systems and efficient and scalable ground segments, together with the establishment of lean regulations and new space legal regimes.

Portugal became a member of the European Space Agency (ESA) in 2000 and has efficiently used its membership for building-up a scientific and business space ecosystem (over one hundred national entities), relying upon a young generation of scientists, engineers and entrepreneurs that managed to scale-up a number of space companies to be competitive in European and international markets.

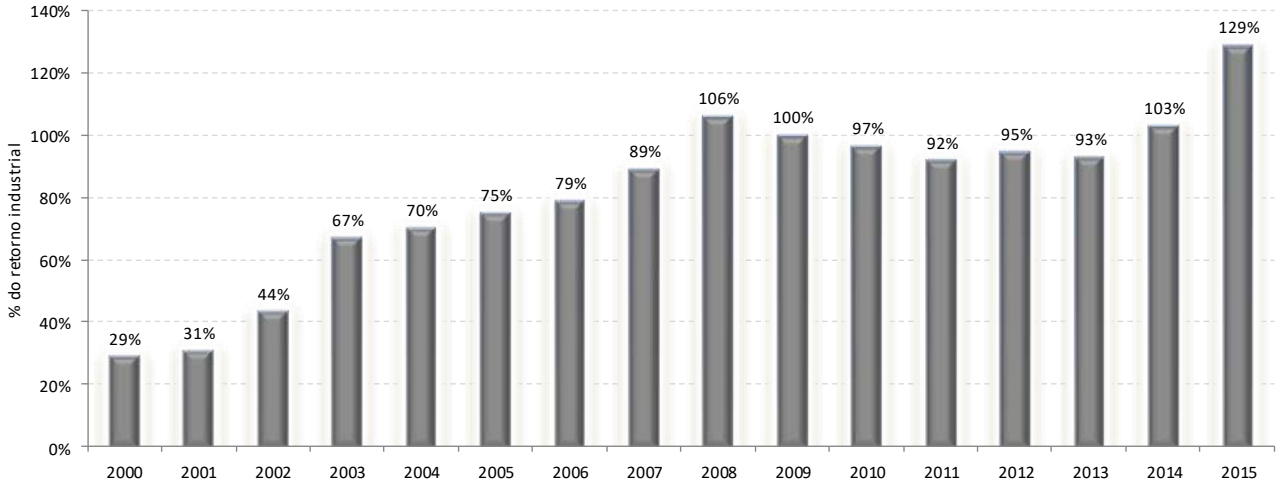
Portugal invested in ESA close to 230M€ in the period 2000-2015 through the public budget attributed to FCT and managed over the last 15 years through the “FCT`s Space Office”. As a result of this investment, Portuguese business space ecosystem has an economic return from ESA over 120% for the last decade. This was due to the effort of scientists and companies in developing skills and competences in a range of diversified areas, including telecommunications, cyber-physical systems, machine learning and augmented reality, earth observation, navigation systems, space exploration, and launchers technology, among many other sub-domains.

The return on investment presented by ESA and measured by the OECD shows "a multiplier effect between 4 and 5 of the public funding of research and technological development activities with an even greater impact on the creation of highly qualified jobs" in the European space. An economic impact study published by FCT in 2010 showed that for each euro invested in ESA space programs a return of more than two euros is generated for the Portuguese space sector.

The technological performance of the national entities in the ESA is reflected in the overall industrial return levels (in all programs, see Figure below), which approaches 130% in 2015, showing that national entities have the capacity to capture a higher number of contracts for the supply of products and services at the value of the subscription of Portugal to the family of programs referred to above. As a consequence of this technological capacity, it is currently estimated that the multiplier effect for Portugal is closer to the European average.

The Portuguese business space ecosystem involves a total work force of over 1400 people, including 300 highly qualified engineers are fully working for the space sector, generating in the period 2006-2015 a global turnover worth around 890M€. The built-in capacity leveraged Portugal as a competitive player in European funded projects, with an overall return of 22M€ for the period 2006-2016. In addition, Portugal and ESA established a joint business incubation program that is expected to generate 30 start-up companies and 240 highly qualified jobs by 2018.

Figure 1.6
ESA Industrial Return for Portugal, 2000 - 2015



The total financial volume of 10 reference companies in the national space sector during the period 2005 to 2015 amounted to around € 889.4 million. Of this total, 140.8 M € (16%) corresponds to the financial volume of space activities (Table below). This distribution of the financial volume proves that the main companies of the Portuguese space ecosystem can succeed in the market without being totally dependent on public financing of the sector and that companies are leverage space and offer technological solutions unique to other markets.

Table 1.3
Financial volume in the space and non-space sector of a sample of 10 entities involved in the space sector during the period 2005 to 2015

	Turnover Space	Turnover non-Space	TOTAL (M€)
GMVIS SKYSOFT	36,6	19,7	56,3
CRITICAL SOFTWARE	32,6	103,3	135,8
DEIMOS	29,5	0,0	29,5
ISQ	10,2	552,4	562,6
EDISOFT	9,3	12,2	21,5
LUSOSPACE	6,2	1,9	8,1
ACTIVE SPACE TECHNOLOGIES	5,8	4,2	10,0
HPS	4,6	0,2	4,8
OMNIDEA	3,4	3,2	6,6
TEKEVER	2,6	51,6	54,2
TOTAL (M€)	**140,8**	**748,6**	**889,4**

The specific context of Portugal: Atlantic positioning and the potential for a space port

Space science and technology play a major role for the provision of low cost access to Space through safe and reliable spaceports, as well as satellite control and data transmission and collection. Portugal has a unique location in the Atlantic and the Azores islands are particularly suited to consider the development of a spaceport infrastructure for launching satellites (large, medium and mini-Nano “constellations”). Their geo-strategic position (EU territory in Schengen Area, close to Continental Europe, Extensive ocean coverage over 1500km in any direction) provide critical advantages for promoting “new space industries” and a potential spaceport in the

Azores could have a dual use, if close to an airport, where space vehicles could land from the International Space Station (ISS) with cargo missions, crewed or uncrewed transportation to and from Low Earth Orbit (LEO).

In addition, the market for a low-cost spaceport in the European territory is very promising, with an expected increasing demand for deploying constellation of Nano-satellites at a fraction of current costs, as well as replenishing and maintaining large constellations of 10 to 200kg-class satellites, or launch single 10 to 450kg satellites. The economic development opportunities are very promising, with a potential multiplier effect of 4 linked to the investment that can be made in such a challenging space project (considering grounds facility, launch campaigns, logistics, meteorology, telecommunications, safeguard and safety, payloads preparation, telemetry and radar, general communication among other indirect outputs).

The goal of a new strategy "Portugal Space 2030", together with a Portuguese space agency, considers an innovative public-private initiative together with a "lean" institutional vehicle intended to promote Portugal as a place of innovation, based on science and business capability, generating high-level jobs and inspiring young generations towards Space technologies and related applications for society at large.

The agency is intended to establish new business and research opportunities by taking advantage of the scientific community, industry, government and "New Space" entrepreneurs in an international context. The tasks associated to these objectives are many and important enough to justify the creation of a new agency, as follows:

- Promoting the uniqueness of Portugal and its Atlantic location for research and international cooperation in Space related areas, thus contributing to progress;
- Developing key capabilities able to attract space scientists, engineers and entrepreneurs for Portugal, from all over the world, with particular focus on Atlantic countries (USA, UK, Brazil, South Africa);
- Building up international partnerships, public and private, able to place Portuguese space technology on a sustainable path;
- Evaluating and selecting proposals made by scientists and/or entrepreneurs willing to use existing capabilities;
- Liaising strategy, plans and activities with scientific communities and entrepreneurs;
- Taking initiatives for investing in relevant upstream technologies, as well as technology and system demonstrations able to provide Portuguese enterprises with a leading position in upcoming and promising commercial products and markets;
- Stimulating interest and proposals from non-space industrial and economic sectors ready to invest in value added downstream products and services.
- Defining the legal, fiscal and financial framework able to attract private investors to Portugal;
- Developing a national space law for covering the governmental responsibility for the space aspects of selected projects;
- Authorizing and controlling the activities of selected entrepreneurs according to the national law;

The above represent the tasks which are necessary to be fulfilled by the new agency and that the government cannot delegate to existing entities. The experience learnt form successful space agencies worldwide allows outlining the main characteristics to be promoted for a new space agency for Portugal as follows:

- Knowledgeable, to be trusted by its stakeholders and partners, and to be able to manage risks;
- Attractive, to be able to attract stakeholders and partners ready to share objectives and risks, as well as to attract the best talents;
- Autonomous, to be able to decide quickly and to be able to take risks;
- Agile, to be able to react quickly and embark into new missions without a long and risky transformation;
- Light, in terms of own functions and resources, excluding any function able to be outsourced and which could introduce rigidity.

The development of the agency should follow a stepwise approach, with funding to be made available from both public (government) and private sources, in a way to stimulate innovation and create value along the end-to-end chain, from either research to market, or from market to research.

Although it has been difficult to mix public and private funds because of their different purposes and criteria, a link between the two types of investment funds is important for connecting potential technology/science progress into value and profit. At least two separate funding sources are therefore necessary to guarantee:

- Risk-taking, through investments in science and technology, and risk-sharing with enterprises, through investments in demonstration and development, which requires a source of public funding;
- Activities driven by applications and markets, requiring a source of private funding;

The link between the two sources of funds may be organized through minority cross-participation, as well as through the role and actions of the Space Agency as the “investment committee” of both funds, in charge of optimising the end-to-end value chain. The funds required to operate the agency itself should be kept to a minimum, so as to provide priority to external actions. Nevertheless, they should be sized so as to enable attracting the best from the world and from different economic/industrial sectors.

4. On the sustainable management of water and energy provision and food systems in the Mediterranean area

A new international R&D and innovation agenda focused on the sustainable management of water and energy provision and food systems in the Mediterranean area has been planned, as aligned with the European initiative PRIMA – Partnerships on Research and Innovations in the Mediterranean Area. Climate change is increasingly causing severe water shortages in the area, with major impacts on agriculture. Most water available is used for irrigation. This means that such shortages result in decreasing and irregular crop yields, putting additional pressure on natural resources and on the capacity to provide clean water and affordable food for the region's inhabitants. This in turn has a negative effect on nutrition, health, livelihoods, standards of living and levels of wellbeing.

Launched at the 2nd Euro-Mediterranean Ministerial Conference in May last year in Valletta, Malta, through the Declaration on Strengthening Euro-Mediterranean Cooperation through Research and Innovation, PRIMA aims at a growing effort of diplomacy and scientific cooperation between Europe and the Mediterranean countries with the aim of transforming the region into an area of sustainable economic development and cultural exchanges.

PRIMA was publicly presented on February 7, 2018, in Lisbon. It is a 10-year funding program representing € 440 million divided between contributions from participating countries and the European Union through the Framework Program for Science and Innovation H2020 with a view to supporting Research and Development activities in three pillars: (i) sustainable water management in arid and semi-arid areas of the Mediterranean; (ii) sustainable farming systems; and (iii) food value chain in regional and local Mediterranean development.

Portugal has been a pioneer in this process of high international and political relevance and we are effectively taking on new challenges in this context. PRIMA operates under Article 185 of the Treaty on the Functioning of the European Union, with a dedicated implementation structure (Dedicated Implementation Structure-DIS) based in Barcelona, Spain, assuming the legal personality of the Spanish Law Foundation, the Foundation COUSIN. Portugal, through the FCT, was founder of this Foundation and committed € 7.5 million over 10 years.

Several Portuguese scientific 'communities' are well integrated in PRIMA´s goals, namely: i) the communities, at large, involved in the national strategic resercah and innovation actovities covering agriculture; ii) the communities participating in the successive competitions for research projects in which FCT has participated in the scope of ERA-NETs that helped to leverage PRIMA; and, above all, iii) the five national networks promoted by the ministers of Science and Agriculture dedicated to agricultural, viticulture and animal research, food and mountain security (AGRO-TECH, Alentejo AGRO Net, Rexia 2, Riev 2 and RNIM). It is also worth mentioning that representatives of these communities, as well as the Ministry of Agriculture (INIAV), the Ministry of Foreign Affairs (representation in the Union for the Mediterranean) and the business world (Agrocluster) have been involved in several PRIMA preparatory meetings.

In addition to actively participate in PRIMA, the Portuguese strategy in the field of "Precision Agriculture" considers strengthening new collaborations between research and entrepreneurial communities, namely in the form of Collaborative Laboratories, as well as between Fraunhofer Institutes and Portuguese research institutions, including establishing in Portugal a new Fraunhofer center dedicated to the theme "Precision Agriculture", together with long-term research networks between Fraunhofer and Portuguese research institutions. The cooperation will be focused but not limited to the following topics :

- Smart agriculture and forestry in Mediterranean areas including smart sensors and digital solutions
- Early detection of pests and diseases using advanced monitoring systems
- Exploring combinations of ceramic filtration, thermal and electrical treatments for the low-input stabilization and quality treatment of wines and waste streams
- Earth Observation Data Platform for Support to Wine Production in the "Região Demarcada do Douro"
- Water resources for irrigation: quantity, quality and spatial localization.
- Sustainable agriculture by means of closed cycles for nutrients, water and energy on local and regional level.
- The integration between rain fed and irrigated agriculture and the sustainability of the territory.
- Irrigated summer crops and new added value products.
- Energy sustainable agriculture.
- Full resource use and integrated valorization of crops from agricultural and agro-forestry systems

5. Clinical Research and Biomedical Innovation

The creation and development of a "Clinical Research and Biomedical Innovation Agenda" aims to help growing clinical and biomedical research in Portugal, together with biomedical related industries. It should also consider the promotion of medical physics in Portugal in close international cooperation, with specific applications for the health sector (i.e., Cancer clinical research). It should contribute to retain highly skilled human resources and contribute to regional growth.

It involves the creation of a "Clinical Research and Biomedical Innovation Agency", through a flexible public private partnership and governance model will provide financial contributions to promote and expand biomedical companies and activities, as well as related international scientific programs in emerging areas of clinical testing, medical devices, and nuclear technologies, among other health related issues. Main opportunities and challenges are as follows:

- Research and Development in the health sector in Portugal has been considerably strengthened over the last decades, but remains unbalanced in terms of relatively weak practice-related activities, including clinical research, clinical innovation and medical technologies. The promotion of a more balanced development together with the promotion of clinical research and biomedical innovation is crucial to foster progress in the health sector and should therefore be given utmost attention. The recent establishment of *Clinical Academic Centers* throughout the country, gathered in the *National Council of Clinical Academic Centers* (NCAC), represents a strong political and institutional commitment in this regard. However, an investment boost is needed to leverage this sector.
- It should be note that most of the investment in health related R&D over the last decades has been made through the *Portuguese Science and Technology Foundation*, FCT, with an overall annual value in 2016 of about 30 M€ (including all funding lines, of institutions, fellowships and projects). In addition, about 6 M€ have been annually invested in joint academia-industry projects funded through the National Innovation Agency, ANI.
- A structured program is necessary to expand the overall level of investment and to open new opportunities for clinical research and biomedical innovation. The promotion of a "Clinical Research and Biomedical Innovation Agenda", together with the creation of a *Clinical Research and Biomedical Innovation Agency* will be extremely important in achieving this goal, as long as it is guided by high quality standards in R&D, entrepreneurship, professional training and clinical practice. Such agency should aim to plan and implement the following measures:
    - Identification, selection and funding of high quality projects and programs in clinical R&D and biomedical translation. These actions will follow the best practices of international reference of peer-review, with neutral and independent evaluations;
    - Support, co-development, internationalization and sustained progress of the state-of-the-art clinical activity and R&D in the areas of translation, clinical and biomedical innovation of high quality;
    - Advanced medical and biomedical education and other measures deemed necessary to attract, develop and retain the best researchers in the health sector, with the further aim of improving the health of the population;
    - Communication to the community to promote dialogue between health care providers, researchers, patients and society in general on the benefits of clinical and biomedical R&D in the spirit of an Open Science guided by ethical and transparent principles;
    - Articulation between clinical and biomedical R&D, on the one hand, and other health research activities, on the other, maintaining a focus on research oriented towards health priorities defined for Portugal, taking into account, among other planning instruments, the National Health Plan, Priority Health Programs, the Integrated Strategy for Rare Diseases and the EU R&D Framework Program on Health, Demographic Change and Welfare (Horizon 2020);
    - Assist the government in translating health priorities into R&D health priorities, within available financial resources. This exercise will involve the main stakeholders: researchers, health professionals, the health products and services industry, patient associations and other users of research results;
    - Evaluation of the impact of the implemented actions and programs, taking into account their objectives, the RCBIA mission and the health priorities defined for Portugal;

- Coordination with FCT and ANI in order to promote an ongoing pipeline of investment, from basic research to clinical validation and commercial availability of new products and technologies, whether for prevention, diagnosis, prognosis, therapy or rehabilitation in the area of new medicines, medical devices, improvements in good practice, among others.
- Promote conditions for technological development in the field of bioimaging, medical simulation and nuclear technologies applied to clinical research and provision of advanced health care in priority areas for the Portuguese health sector such as Cardiovascular Diseases, Oncology, Diabetes / Obesity and Multiresistant Bacteria.
- In addition to the support given to proof of concept projects, exploratory projects, clinical research and infrastructure, the Agency, through a flexible public private partnership and governance model, will provide financial contributions to promote and expand biomedical companies and activities, as well as related international scientific programs in emerging areas of clinical testing, medical devices, and nuclear technologies. It is expected that the expansion of new biomedical industries and technology-based businesses will provide a total revenue of 16M€ during 2020-2039 following an investment of 12M€ during 2017-2020.

6. Digital skills and Digital transformation

The world we live increasingly relies on digital technologies, so it is important that everyone has the competences to deal with this new reality. The new practices tend to be based online, and users normally interact with them through electronic devices. In the case of the active population, learning, productivity and competitiveness are also increasingly dependent on digital factors, meaning that there is a growing need for digital competences in many different professions.

Even though Portugal is close to the European median in terms of digital competences (15th in the DESI 2017 Index, Digital Economy and Society Index of the European Commission), it needs to reinforce basic Information and Communication Technologies (ICT) competences, especially in terms of human capital and internet usage levels, preventing them to stay at a worrying threshold. This is also true for specialists, who need to be able to take advantage of the growing availability of jobs in the digital market.

To this end, we have a training infrastructure as well as the human potential capable of being (re)qualified to meet the demands of employment opportunities typical of modern societies. However, this (re)qualification is a demanding task that requires mobilisation and a combination of efforts from different areas of governance and civil society. This is the 21st Government's purpose with the "National Digital Competences Initiative e.2030, Portugal INCoDe.2030".

Portugal needs to promote a new set of digital competences with a view to making the most of the opportunities the future will bring, and generating renewed confidence in the new generations.

These competences, which have been planned up to 2030, are part of exercising full citizenship. A country with digitally proficient citizens is also a country where more people are included, involved, and able to deal with the society they are part of.

Digital competences are also intrinsically linked to employability - increasing digitalisation in the labour market requires new competences. A more skilled active population generates more new jobs, as well as innovative markets and products, generating more competitive and robust economic activities.

At the same time, the country itself must be an active agent in the global effort to produce new scientific computing knowledge and develop the capacity to manage and use large amounts of information. This will help to ensure a better position in Europe and the world. We cannot wait to find out what the new technologies will be; we have to create them and work with them.

Creating a more resilient society involves developing new competences, particularly digital ones, which are constantly changing and evolving; at the same time, it involves preparing people for growing uncertainty, recognising that there are differences that will require unique preparation models.

It is in this context that the Portugal INCoDe.2030 initiative includes a public policy integrated action that aims to stimulate and guarantee the development of competences as tools to help prepare the new generations for the "unknown", investing increasingly in new knowledge and in the capacity to create new jobs - more qualified and better paid - encouraging entrepreneurship in young people.

It should be clear that Portugal´s INCoDe.2030 initiative addresses the concept of digital competences in a broad manner. It includes the notion of digital literacy (i.e. the ability to access digital media and ICTs, understand and critically assess contents, and communicate effectively), as well as the production of new knowledge through research, which involves processing information, and communicating, interacting with and producing digital content.

The concept of digital competences is also linked to the use of digital technologies to design new solutions for different types of problems, the integration of interdisciplinary knowledge and data analysis, intensive use of artificial intelligence, the use of advanced instrumentation and communication networks and mobile systems, and the development and programming of cyber-physical systems. This involves hardware and software and extends the concept of ICT to electronics, automation and robotics1.

Competences can be developed to different levels of depth and proficiency in each of these areas, depending on the level of qualification and set goals. These different levels are reflected in the type of measures that will be promoted in an inclusive manner.

Program Action: Portugal INCoDe.2030 initiative

To address the challenges outlined above and the targets identified in Table 1, the Portugal INCoDe.2030 initiative has proposed a wide range of measures that will mobilise the various governmental bodies. These measures should work alongside the civil society initiatives which have similar aims. These measures are structured around five main action lines.

Action line 1: INCLUSION

Ensure that the whole population has equal access to digital technologies to obtain information, communicate, and interact with others.

In view of the increasing digitalisation of the world today - from education to industry, from entertainment to social life, from cities to farms, from medicine to the environment - it is essential that the people of Portugal have the competences and the means to use digital technologies.

However, in order to achieve this, there are numerous obstacles and limitations to overcome for many citizens, namely those who have already left formal education and are not exposed to many vocational training. Thus, to ensure a level of fairness and social cohesion that will lead to balanced and sustainable development, it is essential to raise the population's awareness about the importance of digital competences, specifically by creating resources and content centres and user training campaigns. This must be done while ensuring territorial cohesion, taking into account the need to reinforce the use of broadband services. In order to achieve these objectives, it is critical to strengthen gender equality in terms of access to and development of digital competences; as well as promote regional approaches, bridging the inequality that still exists in Portugal.

Action line 2: EDUCATION

Ensure the education of the younger population by stimulating and reinforcing digital literacy and digital competences at all levels of schooling and as part of lifelong learning.

Preparing citizens, now and for the future, involves developing competences that go beyond simply coexisting with digital technologies; it is also about helping people to improve their understanding through the early acquisition of knowledge at the level of a frequent user.

This involves developing logical reasoning competences, collaborative work and even, in many cases, development (programming) competences.

It is therefore essential that the new generation is equipped with these competences through permanent and coordinated education and vocational training systems. This task includes reviewing program contents and teaching processes, developing digital didactic and educational resources, ensuring adequate technological infrastructure, promoting the training of teachers and trainers, and ensuring lifelong training. In order to achieve these objectives, it is essential to fully integrate digital competences and resources into the teaching processes.

Action line 3: QUALIFICATION

Capacitate the active population by providing them with the knowledge they need to become a part of a labour market that relies heavily on digital competences.

The need for ICT competences in the labour market has been growing very significantly; and, despite the still-high unemployment rates, particularly youth unemployment, the response to these needs has not been enough. The disparity between the needs of the labour market and the availability of qualified professionals requires a multi-faceted intervention to reinforce ICT training, particularly to meet the demanding challenges of the progressive digitisation of business activities and industry (i.e. "Industry 4.0").

Thus, in the immediate future, it is a priority to train intermediate-level technicians in well-defined areas, aimed at specific economic sectors. These sectors have to be involved in the process, by creating a network of academies and digital labs, providing internships, and creating spaces for joint/collaborative training.

At the same time, professional re-training in digital competences should not be neglected. There is a need for intensive ICT and advanced training preparation for teachers and educators, whether the education leads to a degree or not, both for the economic sectors, and for the cultural sectors and Public Administration in general.

Action line 4: SPECIALISATION

Promote specialisation in digital technologies and applications to improve employability and create higher added value in the economy.

Although the demand for professionals with digital competences is a reality in every activity sector today, in the European Union, more than half of professionals with digital competences are already working in ICT-intensive sectors. In addition, new markets and products are emerging in areas which, until recently, appeared not to have any need for such competences. This is true in health, agriculture, fishing, industry, energy, cities, mobility and transport, environment and water resources management, public security and defence, construction, tourism and creative industries, retail and distribution, banking and insurance, education and training, etc.

In this context, it is important to improve the range higher education at all levels, from short technical courses (TESP), to 1st and 2nd Bologna cycles as well as post-graduate programmes in the priority areas of this initiative, focusing on cooperation between Higher Education Institutions, research units and companies in their development and training, while enhancing active educational procedures that include training at work.

It is also important to launch a network of digital innovation laboratories and ensure that specialised training is a national priority, reinforcing the current training on offer through TESP undergraduate and masters' programmes, and post-graduate degrees; intensifying advanced training programmes throughout working life, and encouraging specialisation in key sectors for Portugal.

Action line 5: RESEARCH

Ensure conditions are in place for the production of new knowledge and active participation in international R&D networks and programmes.

The initiative to plan the development of digital competences up to 2030 aims to contribute to the advancement of science and digital technologies. The resilience of our society and the competitiveness of our economy need to be strengthened through a virtuous cycle, which not only requires a strong involvement from society in the production of new knowledge but also the translation of this knowledge into societal and economic benefits.

Thus, Portugal must strengthen its participation in scientific production in all areas of knowledge, but especially in areas involving advanced digital competences; such as handling and analysing big data, computational biology and bioinformatics, photonics, advanced computing in general, cognitive computing and automatic learning, cybersecurity, and cyber-physical systems. In this context, it is important to promote scientific activity in four major key areas:

- Advanced Cyberinfrastructure (ACI) - including all advanced scientific computing fields.
- Computing and Communication Foundations (CCF) - including quantum computing, among other areas of R&D.
- Computer and Network Systems (CNS) - including big data, cloud computing, and IoT, among others.
- Information and Intelligent Systems (IIS) - including artificial intelligence, as well as human-centred computing in relation to digital media.

In this context, it should be clear that promoting new competences in these areas can and should facilitate knowledge of social and cultural phenomena, among others, by mobilising data processing in an effective way in all areas of knowledge, health, culture, and the study of social processes.

It is important to work towards widespread access to scientific information and create conditions for cooperation between laboratories based on an advanced scientific computing network; as well as promote international collaboration, especially by maintaining programmes that are carried out with US universities and extending these programmes to other universities and to other countries.

7. International partnerships in research and academia with science based entrepreneurship - "Global S&T Partnerships Portugal – GoPortugal"

The initiative **"Global S&T Partnerships Portugal – GoPortugal"** considers a new cycle of **international partnerships in research and academia**, involving universities and polytechnics, as well as promoting science based entrepreneurship to foster the creation and development of new technology businesses.

The main goal is to foster scientific research in Portugal at the best international level, together with improving the impact of scientific research and technological breakthroughs into economic and social gains for Portugal and for the World. This considers science and technology ventures with an international scope and nature, with emphasis on stimulus for skilled job creation and scientific employment in Portugal through science-based business ventures oriented towards global markets.

On-going public and private international partnerships and related initiatives will be further strengthened, together with public-private partnerships oriented to change the national economic paradigm by fostering the creation and growth of science-based startups and industry-science partnerships that leverage science and technology in Portugal to address global markets. This requires: i) Direct funding of proof-of-principle R&D projects; ii) international science-based business development activities of early-stage companies and research groups; and iii) Direct investment in early stage science-based companies based on scientific or technological breakthroughs.

The context: ***International Partnerships in science and technology, 2007-2017***

In recent decades Portugal has witnessed a dramatic growth and improvement of its scientific foundations, both in terms of human resources and of infrastructure. Particularly important progress has been made in areas such as communications, energy, healthcare, material science and aerospace, among many others. Through privileged access to Portuguese research institutions and deep ties to the diversified structure and organization of research groups throughout the country in all scientific areas, GoPORTUGAL aims to act as a catalyst for the translation of scientific progress into products and services that not only benefit populations directly but also help position Portuguese R&D institutions at the forefront of technological innovation.

This is possible to be achieved because strengthening the internationalization of tertiary education and S&T is recognized, at large, as a way to stimulate the integration of national institutions in emerging scientific networks at an international level.

In this context, a unique set of international collaborations with leading institutions worldwide has been launched in 2007 and has been successfully developed through the years.

The main objective of international partnerships in science and technology has been to facilitate the internationalization of Portuguese higher education institutions, research organizations, and companies fostering their integration into thematic networks of world-class research, advanced education and business. The international partnerships promoted a cultural change on how the research ecosystem collaborated in Portugal enhancing closer ties of scientific cooperation, training of highly qualified human resources, generation of economic impact through S&T based innovation and entrepreneurship.

To highlight some of the core activities of the partnerships, is worth to mention the strategic combination of world-class masters, doctoral and post-doctoral education degrees, cutting-edge research, and a close collaboration with the Portuguese industry sector, that include a number of key unique (born in Portugal) initiatives that support the national entrepreneurial ecosystem.

This collaboration was developed through university-industry-government relations with an oriented focus on economic impact and societal gains for Portugal. The following should be noted:

- The **MIT-Portugal Program, MPP** joint venture (www.mitportugal.org) has operated since 2007 in the field of "engineering systems", and has particular emphasis on the complex processes associated with energy systems, bioengineering, transportation, and industrial production. MPP has engaged joint research teams working in both sides of the Atlantic and supports exchange of faculty and students. It has reinforced partnerships between Portuguese universities and industry.
    - During the 1st phase, 2006-2012, MPP involved 6 Key Portuguese universities, 20 Research Centres and National laboratories, and 210 Portuguese faculty members, together with 25 MIT departments,

all 5 Schools within MIT, and 70 MIT faculty members. Twenty projects were funded through competitive calls (2008 and 2009), involving Portuguese institutions and companies in collaboration with MIT research teams. Four PhD Programs were created as well three Master Programs. The programs had 858 students enrolled at Portuguese universities (253 PhD grants and 7 Post-Doc grants) from 44 countries around the world. By the end of 2015 MIT-Portugal had 123 PhD and 190 MSc Graduates. Altogether, 71 new courses have been developed for teaching in the various education programs, many of which introduced curricular elements novel to the Portuguese and international engineering education.

- For the 2nd phase, 2012-2017, the became focused on the development and implementation of research projects (Test-beds) in areas of high economic importance and technology commercialization potential to ensure the maximization of knowledge transfer and the translation of technology-based ideas into economic value. One competitive call was launched in 2014 and 3 projects were financed. The MIT-Portugal also foster innovation and entrepreneurship through a series of actives that help to developed about 17 spin-offs or start-ups that.
- The Innovation and Entrepreneurship Initiative, http://buildingglobalinnovators.eu/, has complemented and branded bythe *Building Global Innovators* (BGI) competition, an international venture competition that aims to promote entrepreneurship and encourage business value models and transfer from the academia to the markets. This venture competition has the following results: 5 Editions of the BGI; 515 submissions; Participants from 37 countries; 32 M€ Capital raised by semi-finalists; 300 jobs created; 79 active start-ups.
- Another joint programme was launched in co-operation with the MIT Sloan School of Management in 2008, aimed at creating an international MBA, the "Lisbon MBA" (www.thelisbonmba.com), which is offered through two top Portuguese business schools, the Portuguese Catholic University and the New University of Lisbon. It is a full-time degree programme in business administration framed in an international environment with a focus on both the academic component and the interpersonal competencies that develop strong business leaders. It involves co-funding from seven major Portuguese companies and banks and will stimulate new research and enhance the quality of education in management sciences in Portugal.
- The collaboration with MIT was further extended through an attempt to launch a strategic joint research collaboration agreement with the International Iberian Nanotechnology Laboratory (INL, www.inl.int). This laboratory was created by an international treaty between Portugal and Spain signed at the end of 2006, and is now in the stage of development of operation in Braga (northern Portugal). It is expected to become an international institution of excellence in the areas of nanomedicine, environmental and food control, nanoelectronics and molecular manipulation, and will engage about 250 researchers from all over the world. The annual operating budget is funded equally by Portugal and Spain. The Laboratory plans to develop strong collaborative links with industry and will foster new research cooperation worldwide. In particular, INL has been launched together with Portuguese-Spanish networks oriented towards new developments and applications of nanoscience's.

- The **Carnegie Mellon-Portugal Program** (www.cmuportugal.org) mission is to place Portugal at the forefront of innovation in key areas of Information and Communication Technologies (ICT), by promoting cutting-edge research, world-class graduate education and a close collaboration with the Portuguese industry. The CMU-Portugal Program is an educational, research, and innovation platform aimed at developing an ecosystem of high quality (dual degree) graduate academic and research program that fosters the emergence of new concepts in information and communication technologies, with an orientation towards new products and services for markets worldwide.
  - The Program collaborative network involves 15 Portuguese Universities, four Associated Laboratories and many other research institutions in Portugal, 11 CMU departments, more than 90 companies, and over 400 faculty and senior researchers in Portugal and at CMU. During the 1st phase of this Program innovative projects with a strong industrial participation (25 Collaborative research projects with the involvement of 26 companies) were funded; stable education programs (7 PhD dual Programs and 4 dual Professional Master Programs, more than 226 students have been recruited internationally and 90 PhD grants were funded, 10 students graduated from the Program), and a constant flow of people and knowledge between Portugal and US (over 150 Portuguese faculty and

senior researchers have been involve in the activities of the Program and 28 Portuguese faculty have been thought the CMU-Portugal Faculty Exchange Program).

- The Program also has been promoting a new generation of technology based companies in telecom, software and related areas (10 companies have been started by faculty or students of the Program). The 2nd phase started in 2013 and is focused on innovation and technology transfer. New competitive project calls were launched called ERIs - Entrepreneurial Research Initiatives (6 projects were funded) and Early-Bird Projects (10 projects were funded) for exploratory research (10 projects were selected), the doctoral programs funded 15 PhD Grants. The Program aim is to create a dynamic ecosystem of companies and research units that can speed up and improve knowledge transfer.
- The most significant initiative of the Program to support the creation and development of start-ups in Portugal, and to promote their internationalization inRES is targeted to entrepreneurial teams that want to start a company and commercialize a technology, have proven technical feasibility of their product or service, are not yet established companies regularly selling their products or services and have had enough initial interaction with their target markets and industries with a consistent product or service and/or business concepts. This program provides entrepreneurial teams a training period in Portugal, followed by a 2 month structured immersion period in Pittsburgh anchored at CMU. By now the inRES organized 3 editions and a total of 9 teams were selected.

- The **University of Texas in Austin-Portugal Program** has launched the Collaboratory for Emerging Technologies (CoLab) (www.utaustinportugal.org), focusing on collaborative research in advanced interactive digital media and integrating advanced computing and applied mathematics, and as from the 2nd Phase also focusing on emerging technologies, namely nanotechnology. The program carries out their activities through graduate programs and research projects that aim to create in Portugal a hub on the areas developed by the program. This collaboration also has the involvement of several industrial partners as fundamental members of the research projects financed through the CoLab.
  - The program fosters a new dynamic providing a significant cross-collaboration of academics and researchers. During the 1st phase (2006-2012) of this US Partnership, several activities were promoted in teaching and training (3 PhD Programs and 1 Master Program, 84 PhD grants and 9 Post-Doc Grants, were funded and 25 students already completed a degree), research (20 projects were funded on 1st phase through 2 competitive calls, where 18 companies were involved), exchange programs (for students, researchers and professors), workshops and public exhibitions (Future Places and Monstra Short Film Festival), industrial liaison (fostering interaction with companies), and an annual conference and thematic workshops.
  - The 2nd phase of the Program builds on the achievements of 1st phase, and is set up to create an even more dynamic environment involving innovative collaborative research focused on the development of solutions to problems identified and establishing new business models. The 2nd phase continued the activities of the 1st Phase, funding 8 PhD grants and 10 exploratory and scientific research and technological development projects. The Program has also provided conditions and opportunities for some of the faculty members; students or alumni involved foster their entrepreneurial initiatives. Four spin-offs companies have been created so far as a result of Program activities.

- As part of the collaborations with the University of Texas in Austin, Carnegie Mellon, and MIT, the **University Technology Enterprise Network** (UTEN) was established in 2007 (www.utenportugal.org). It is aimed at commercialization of international technology and the professionalization of university technology managers, and comprises a network of about 40 university and research institutions in Portugal. Working together with counterparts in the US, where new business ventures have been incubated and technology transfer officers trained. A UTEN survey shows that in the period (2007-2012), the network contributed in academic environment to: 20% increased patents granted/year ; 26% increasing executed licenses/year; 137% increasing license income; 132% increasing new academic spin-offs. UTEN also contributed to the following achievements in technologies companies: 127% annual growth in revenue; 37% exporting technology; 38% annual growth in hiring.
  - Launched during the 2nd phase of the UTAustin Portugal program, under UTEN, a new model was developed by creating a Portuguese - Global Innovation Hub for Technology Business Incubation and Acceleration in Austin called **Global Start-up program** (GSP) (http://utenportugal.org/global-

innovation-hub/). This is the first operation of its kind to focus on nurturing Portuguese early stage start-ups and selected mature technology companies to expand beyond the national or European markets.

  - This structure fosters cross-border Portugal - U.S. businesses and covers a broad range of technologies including health (med-devices, biotech), ICT, energy, nanotechnology, etc. During the period (2011-2013), the IC2 Institute nurtured the GSP present model by first developing a pilot called US connect pilot aimed to help Portuguese start-ups make the transition to global markets, primarily by closing business deals in the US, 11 companies were chosen. In 2013, 7 companies were recruited from 13 major technology commercialization and incubation entities across Portugal. In 2014 a new call was launched and 9 companies were recruited. In 2015 new companies were recruited and this translated in 18 companies working with the Program, particularly for the US market.

- The **Harvard Medical School-Portugal Program** (www.hmsportugal.org) was launched in May 2009 to foster translational and clinical research programmes and the development of new infrastructure for delivering information produced by medical schools to medical students across academic institutions, health practitioners, and the general public.
  - This innovative collaborative framework contributed to strengthening the relationships between medical schools and health science institutions and their main constituencies. The Program had 38 medical specialties, and 20 international partners, 18 Medical Schools and Laboratories and more the 100 Medical Experts involved. During the program, 33 projects were financed (13 Clinical research projects; 6 Information production and assessment projects; 10 junior research awards; 4 senior research awards).
  - The program had one major workshop every year - the Clinical Scholars Research Training Certificate Program (CSRT) for those MDs that desire to acquire rigorous training in the methods to conduct clinical research. The CSRT is proposed to fully exploit the national capacity in R&D within the Health and Life Sciences area, namely clinical research. A Letter of Agreement was signed between FCT and Harvard Medical School on October 2015 for an education/training program – The Portugal-Clinical Research Training Programme (CSRT) to continue until 2020. FCT considers this commitment as a 2nd phase of the connection with Harvard Medical School and continue to build world-class research networks and best practices to Portuguese Health ecosystem.
- Co-operation with the **Fraunhofer Gesellschaft** facilitated the establishment in Portugal in 2008 of the first Fraunhofer Institute in Europe outside Germany, through the Fraunhofer Portugal Research Association (www.fraunhofer.pt). This is an ambitious project focusing on emerging information and communication technologies, such as “Ambient Assisted Living”, to be complemented by the establishment of R&D consortia and cooperative projects involving several Portuguese institutions and Fraunhofer institutes in Germany.
  - The most important outcomes in the 1st phase of this cooperation are: 35 projects; 61 companies involved; 41 institutions involved; 1.4 M€ Return on public investment (turnover from services/applied research). During 2013, there was a transition period where the extension/renewal of the Partnership was being discussed at Governmental level. The outcome of the discussions was positive and the Partnership between Portugal and Fraunhöfer Gesellschaft was renewed for a 2nd phase during the period (2014-2018) with an overall budget of 3.9M€.

Goals for 2030: “*GoPortugal - Global S&T Partnerships Portugal*”

GoPORTUGAL aims to change the national economic paradigm by fostering the creation and growth of science-based startups and industry-science partnerships that leverage science and technology in Portugal to address global markets, making special reference to foster an agenda on “Atlantic interactions”. It specifically aims to professionalize, accelerate and de-risk the:

- Implementation of R&D joint ventures with innovative partners, research organizations and companies worldwide.
- Protection, negotiation and licensing of valuable intellectual property (IP);
- Creation and growth of science-based new companies;

These three goals will be achieved through three main lines of action:

- Direct funding of proof-of-principle R&D projects screened within Portuguese academia (universities and polytechnics) and research centers and laboratories, with emphasis on the agenda on "Atlantic interactions". Funding should complement and provide continuity to previous research funding, and should have the explicit goal of arriving at data that justifies launching privately-funded corporations or direct commercialization of a product or IP for global markets, with emphasis on joint ventures with the capacity to help skilled job creation and scientific employment in Portugal.
- Support to international science-based business development activities of early-stage companies and research groups, in order to accelerate the commercialization of research results and obtain fair economic results for all the stakeholders involved, inventors, their host institutions and investors, as well as to foster social and economic benefits for Portugal.
- Direct investment in early stage science-based companies based on scientific or technological breakthroughs, global relevance and growth potential. Investments by GoPORTUGAL shall be designed to leverage, and if appropriate complement quality private investments, driving the projects to (1) profitability and scalability, (2) capital raise from renowned investors or corporations, nationally or internationally, or (3) successful exit through trade sale or IPO.

GoPORTUGAL will leverage the networks and knowledge accumulated by international partnerships between the Portuguese government and the academic, scientific and technological system and foreign entities, such as the on-going participation in the Iberian International Nanotechnology Laboratory (INL), CERN, the European Space Agency, among other intergovernmental organizations, as well as through the MIT-Portugal, Carnegie Mellon Portugal, University of Texas at Austin Portugal, and the Fraunhofer Portugal joint ventures.

These existing partnerships will serve both as an institutional basis for GoPORTUGAL on the ground and as a bridge to the skills and connections of the non-Portuguese counterparts. In addition, they will serve to help designing new international partnerships, including fostering a new scientific and entrepreneurial agenda to help promoting the Atlantic positioning of Portugal, as well as the participation in emerging Mediterranean based markets.

GoPORTUGAL will also forge permanent working ties to a select group of technology transfer offices and incubators within the Portuguese R&D system, as well as to State agencies, in order to help leverage their existing capacities, explore synergies, and avoid unnecessary, costly overlaps.

The main programs to be considered for 2018-2030, are as follows:

MIT Portugal 2018-2030

The MIT Portugal program for 2018-2030 will consider the following activities and principles.

The Atlantic Ocean is strategic and at the heart of many innovative potentials and has recently driven a new research agenda on "Atlantic interactions", to be implemented in close international cooperation through the "*Atlantic International Research Centre – AIR Centre*". Testbeds around the "blue economy" offer a renewable and regenerative future to the Atlantic governments who lead and collaborate. In addition, digital transformation is inducing new and complex industrial landscapes and innovative activities, facilitating the emergence of "new space" industries, cyber-physical systems, together with service-oriented industries with minimized environmental impact. This will require an intensive use of modeling in design and planning activities, as well as an integrative approach to different engineering areas, including artificial intelligence, cyber security, smart materials, bioengineering and digital manufacturing. Furthermore, emerging industrial landscapes in close association with "new space" and the "blue economy" will enable new paradigms in human-machine interfaces, with an unprecedented range of adaptation processes from both machines and humans.

As a motivation for the new partnership, the MIT-Portugal Program will contribute to the goal of making Portugal the highest quality-of-life country in the world and, simultaneously, leverage MIT's international leadership in solving problems and finding solutions for one of Humanity's greatest challenges: *living in balance with the Earth*. These two goals help set the stage for a productive partnership going forward.

It is under this context that the "main research areas" of mutual interest, as identified during 2017 by MIT and Portuguese researchers, include:

a. **An Earth Operating Manual**, put together through a cognitive platform that curates the quintillion bytes of daily data from ocean, climate, air, and near-space satellites for breakthrough gains in knowledge and solutions to heal Spaceship Earth in one decade. This bold "flagship research area" would incorporate AI, machine learning, and natural language to curate open data from NASA, NOAA, and ESA and synthesize it for the public, policy makers, consumers, and businesses.

b. **Designing at the Speed of Thought**, as realized by designing, manufacturing and launching revolutionary Wafer Satellites and MicroSat constellations focused on the observation of land and ocean use, animal migration, algae blooms, top soil erosion, soil, sea and air pollution, and regenerative agriculture. The digitalization of hardware is where the *Internet of Things* meets the future of manufacturing.

c. **Exploration Testbeds: Ocean, Land and Air**, to enable the world's largest citizen science effort yet, teaming scientists and engineers with the public from all Atlantic countries, to measure, monitor, and regenerate the Earth's oceans, reefs, rivers, ice caps, forests, aquaculture, agriculture, and climate in the shortest possible time to the benefit of all and the disadvantage of no one. Full participation and immersion is envisioned through augmented reality that transports the user undersea or provides a unique orbital perspective.

d. **Cities–Ocean Interface**, by developing a formal network of coastal cities as a subset of the larger AIR Centre initiative. An "Atlantic Ocean Coastal Cities Network" would foster action on solutions for coastal cities of the Atlantic Ocean in mitigating carbon emissions and adapting to the challenges of climate change, including rising water levels. Priorities include the adoption of the internet of things in the different components of urban management, including the ocean–land interface at the location of major cities along the multi-continental edge of the Atlantic Ocean. Likely partners would be a group of major cities, their municipal governments, and associated academics and business partners from member cities.

An important goal of these four "main research areas" would be the formulation and development of coupled technology-policy actions that will deliver economic and equitable solutions for protecting earth's ecosystems through the design of more sustainable cities, the rethinking of the very concept of "city", the implementation of sustainable food-chain control strategies, the development of sea-based solutions for feeding and healing human populations, the exploration of sea- and air-based sustainable energy systems and the design of strategies for adaptation to climate change while also advancing aggressive greenhouse gas mitigation strategies.

The Atlantic, and the related installation of the AIR Centre during 2018, offers a unique testbed to understand both complex natural systems and also the potential to bridge the distinct economies, cultures, histories and priorities of nations with a rigorous international partnership.

Carnegie Mellon Portugal Program

The program will focus on high-impact science that takes advantage of the important opportunities provided by the data economy as a driver of growth and change. This vision should be followed by an agenda that leverages the strategic geopolitical position of Portugal in the Euro-Atlantic region, while also prioritizing the joint employment of doctorates and the advancement of post-graduate education and research in Portuguese institutions.

The program's approach is four fold: i) keep the focus on cutting-edge ICT research aiming at large scale impact on society; ii) partner with industry, governments, and non-profits, both nationally and internationally, to raise the resources required to apply inventions that change the world; iii) leverage the Atlantic interactions to inform, influence, inspire and make visible the opportunities emerging from real-world challenges, constraints and

opportunities of the unique geopolitical location of Portugal; and finally iv) emphasize the growing and central role universities play in the global innovation ecosystem, driving regional and national economic growth.

Universities play a growing and central role in the global innovation ecosystem, driving regional economic growth. For example, on its Pittsburgh campus, the strong working relationship between Carnegie Mellon and world-class technology companies has become a strong differentiator for educational programs. Carnegie Mellon's strong commitment to entrepreneurship, technology transfer, and economic development provides a vital bridge from research to practice.

The Carnegie Mellon Portugal program will build on Carnegie Mellon's experience as a dynamic economic engine in the Pittsburgh region[1] and will open new collaborative opportunities for the recently established Campus in Silicon Valley. Carnegie Mellon sits at the heart of the regional discovery and innovation ecosystems, together with other leading-edge research universities; it includes scientists and engineers in a flexible talent-rich labor market; a vibrant private sector catalyzed by the entrepreneurial spirit; strategic government investments in research and education; public-private partnerships that promote innovative activities; and infrastructure that fosters collaboration across traditional boundaries. In turn, economic development drives and shapes the university's research and academic mission in a virtuous cycle.

The overarching mission of Phase III is to foster **industry-science relationships as agents of change** with the focus on ICT research for social and economic impact. This requires a robust collaboration with cities/regions and companies strongly invested in the program. As such, within ICT, the program will emphasize research missions that are of common interest between academia and their regional ecosystems in the context of the initiative recently launched by the Portuguese Government to further promote digital skills, "INCoDe2030 – National Initiative on Digital Skills e2030". Addressing these mission statements will require interdisciplinary efforts, both within ICT areas and across different contributing disciplines such us energy, bioengineering, design, social sciences, public policy and entrepreneurship. These missions are starting to be identified during visits of Carnegie Mellon and Portuguese faculty to regional stakeholders and several innovative and fast growing Portuguese startups. In the next few months, this interchange will continue, to further establish synergies between these various players.

UT Austin Portugal Program

After ten years of joint collaboration, it is proposed that UT Austin and Portuguese universities develop a joint effort to promote an internationally relevant new research agenda in areas of emerging international attention and relevance. Priority is giving to the joint employment of doctorates and the advancement of post-graduate education and research in a way that promotes new frontiers of knowledge in emerging themes worldwide, including space science and technology, medical physics and nuclear medicine particularly applied to emerging cancer therapies, nano-science and technology, and high performance computing and related themes of data analytics, visualization and artificial intelligence. Simultaneously, the engagement of technology firms and new entrepreneurial initiatives should continue and be reinforced through UTEN, together with the diversification of funding sources for anticipated activities.

The proposed program is to be developed under two main initiatives:

INITIATIVE #1: International Collaboratory for Emerging Technologies, CoLab

CoLab will be an initiative to promote close collaborative research between The University of Texas at Austin and Portuguese Universities and Research Laboratories. CoLab will comprise the creation of four virtual Flagship Laboratories in different areas of knowledge:

[1] See for example the New York Times article, "Pittsburgh Gets a Tech Makeover," July 22, 2017, https://www.nytimes.com/2017/07/22/style/pittsburgh-tech-makeover.html.

Flagship Laboratory 1: "Atlantic Interactions" - Establishes a new research and innovation agenda involving transatlantic and north-south cooperation in complex systems engineering and science towards an integrative approach to space, climate change and energy, earth and ocean science in the Atlantic, together with emerging methods of data science. This research agenda will be developed together with the installation of the Atlantic International Research Center (AIR Center), in the form of an intergovernmental organization to be created through a public-private international partnership with headquarters in the Azores and a network of island regions (Azores; Madeira; Canarias; Fernando Noronha and S. Pedro-S. Paulo, both in Brazil; Mindelo in Cabo Verde; and Bermuda).

The involvement of the UT Austin Center for Space Research (CSR), together with faculty from the University of Texas-El Paso Center for the Advancement of Space Safety and Mission Assurance Research, and researchers from the University of Texas at Rio Grande Valley (RGV), has been very relevant in the design phase of the venture and should become an important component for the years to come. Equally important has been the participation of US, European, South American and Indian "new space industries". A team from CSR and UT El Paso conducted a Spaceport Feasibility Assessment study to the Azores region for the FCT, which has been a major contribution to this new phase of the ongoing international partnership.

In addition, the involvement of TACC at UT Austin has also become very relevant for building new data analytics and visualization methods for earth observation and climate change studies. This involvement will open and expand TACC's international outreach by working with European partners.

Flagship Laboratory 2: "Medical Physics for Emerging Cancer Therapies" – Proposes the development of a new research and innovation agenda involving the establishment of new joint ventures among UT Austin´s Dell Medical School and Cockrell School of Engineering, MD Anderson Cancer Center, and Portuguese research groups in medical physics, proton therapies, and radiation oncology.

The goal is to associate this initiative with the installation in Lisbon of a protonics facility for advanced cancer therapies in a way similar to that existing at MD Andersen and at a few other sites in Europe. Although the initial goal is the start with an international advisory group and training of radiation oncologists at MD Anderson, a future joint initiative on high-energy cancer therapies is envisioned.

Flagship Laboratory 3: "High Performance Computing, Data Analytics and Visualization" - Proposes a new research and innovation agenda involving the establishment of an "International Advanced Computing Network, iAC net" based on close collaboration between the Texas Advanced Computing Center (TACC) and the Portuguese and European advanced computing community. Links with the emerging European network of high performance computing (HPC) should be guaranteed. This is to be established, in a first phase, through the installation of a set of about 20 racks of STAMPEDE hardware from TACC in Portugal and its linkage to the existing national advanced computing infrastructures, the Barcelona supercomputer center and the emerging European HPC network. In a second phase, higher capacity should be made available, through the installation of a new platform, specified and implemented by iAC net.

Specific actions and research on data analytics and visualization should be carried out, together with a number of pilot projects to better assess and exploit the use of advanced computing facilities for big data in a variety of domains, including cities, agriculture, fisheries, earth observation, and security, among other application areas.

The goals of this Flagship Laboratory are to significantly increase the usage of advanced computing resources by the science, innovation and industry communities in Portugal, in close cooperation with international centers mentioned. A comprehensive teaching and support program is to be implemented, to foster the enlargement of the user base with the skills to maximize the usage those resources, aligned with international best practices.

Flagship Laboratory 4: "Nano Materials for New Markets" - Establishes a new research and innovation agenda involving complex materials engineering and science focused on an integrative approach to Nano sciences over diversified applications. The engagement of the International Nanotech Laboratory (INL) in Braga, Portugal, and the various nano-related initiatives at UT Austin should form the basis for this Flagship Laboratory, which is expected to involve a number of entrepreneurial projects and large firms in different domains.

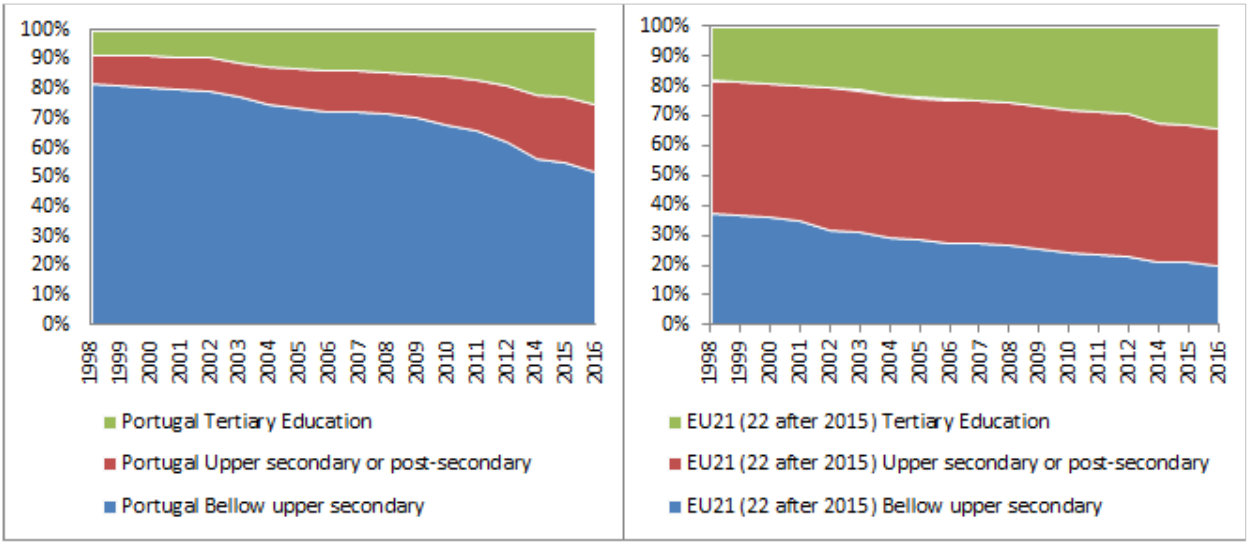
2. Higher Education, Science, Technology and Innovation: data and facts

A. Higher education in Portugal: people, skills and competence building

1. On the qualification of the portuguese population

- A significant structural deficit persist in the Portuguese population: 56% of the employers and 52% of adults aged 25-64 have not completed secondary education, about 45% of the workforce has few or no digital skills, and only 27% of the employed population have a tertiary education qualification (1.195 thousand individuals).
- The proportion of total graduates aged 30-34 was about 34.6% of the corresponding population in 2016, while the corresponding European averages were almost 39% in the same year.
- A significant structural deficit of qualifications remains on the Portuguese population, despite the progress made in the last decades:
  - the percentage of resident population above 15 years with a tertiary degree increased from 0.9% in 1960 (49,065 individuals) to 17.8% in 2016 (1.576 thousand individuals);
  - the number of enrolled students rose from around 24,000 in the early 1960s to more than 400,000 students in the 2010/2011. It was around 361,000 in 2016.
  - the number of graduates grew four times fold in the last 30 years;
  - the share of persons with completed lower secondary education in the labour force is declining since 1998 reaching 48.3% in 2016 (it was 80.3% in 1998);
  - Between 1998 and 2016 the annual average growth of tertiary educated individuals on the labour force was 6.2%.
- A comparison with figures for the European Union (EU21; EU22 after 2015) shows that, the population between 25-64 years old in Portugal is, on average, less skilled than other European countries, although the tendency is to narrow this gap.

Figure 2.1
Educational attainment on 25-64 years old, Portugal and EU, 1998-2016



Source: OECD

- If we consider only the labor force between all the countries in EU (EU28), the trend is the same. According to the Eurostat, in 2016 the share of workers who completed tertiary education was 27.1% in Portugal and 34.6% in the EU28, compared to 12.2% in 2002. In addition, the difference in skills is much noticed when we consider the share of workers whose maximum level of skills was lower than secondary education in 2016, i.e. 46.2% in Portugal, against 16.9% in the EU28 on average.

- In 2015 about 21% of the Portuguese population aged 15-64 had a tertiary education degree (only 12% in 2001 and 16% in 2011), while the EU28 average was 27% in 2015. Regarding higher education qualifications in the labour population, Portugal is almost a decade behind European partners.

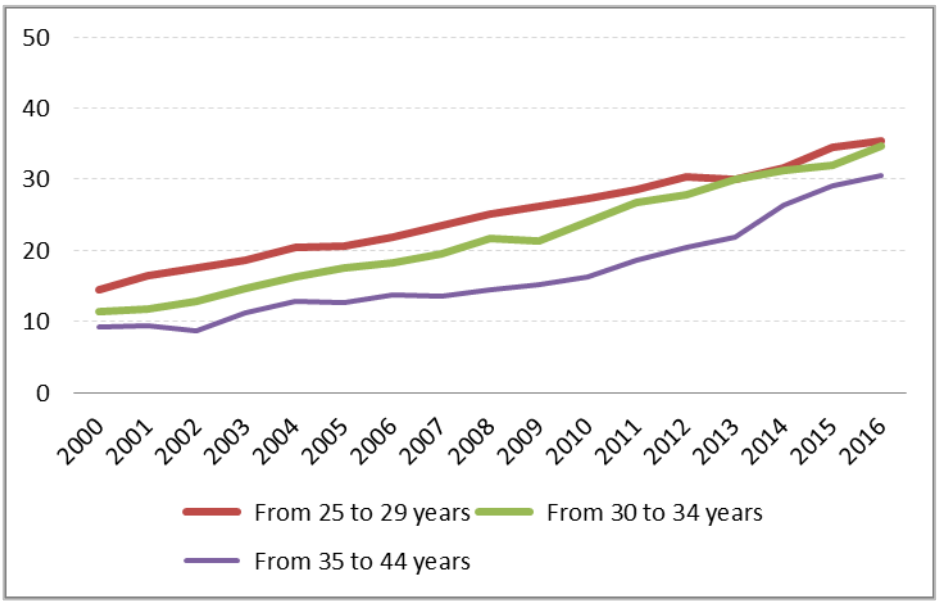
Table 2.1
Population between 15 and 64 years old with tertiary education (%)

	2006	2011	2015
Spain	26,4	29,3	32,1
France	24	26,7	30,4
Netherlands	26,2	28	30,5
Ireland	27,7	33,3	37,4
Portugal	11,7	15,5	20,7
European Union (EU28)	20	23,7	26,7

Source Eurostat

- The lower overall qualification of the Portuguese population is reflected directly in the national entrepreneurial structure, which is inevitably largely directed by employers with low levels of educational attainment, especially on SME.

Figure 2.2
Population with tertiary educational attainment, by age group (%)



Source: INE/Eurostat

- The recent national effort to improve the educational attainment levels of the Portuguese population is more visible when one considers the younger generations. Looking at the proportion of the population with tertiary education, for instance, the upward trend is quite steep, with 11.3% in the year 2000, and 34.6% in the year 2016 in the 30-34 age groups.

2. Access to higher education

- There are different ways to access higher education (1st cycle) in Portugal, namely:
    a) National Competition (public higher education)
    b) Local Competition (courses in music, theatre, dance in public higher education)
    c) Institutional Competition (private higher education)
    d) Several special competitions (available at both public and private higher education) designed to enrol students over 23 years, students with a previous diploma in Vocational Education and Training (Technical Specialization Courses and TESP), students that already have a different higher education degree and International Students);
    e) Another special situations (diplomatic missions abroad or in Portugal, officials from the army, Portuguese Language Speaking countries scholarships, high performance students, students from East Timor.

- The enrolment in 2nd and 3rd cycle is always made through Institutional Competitions.

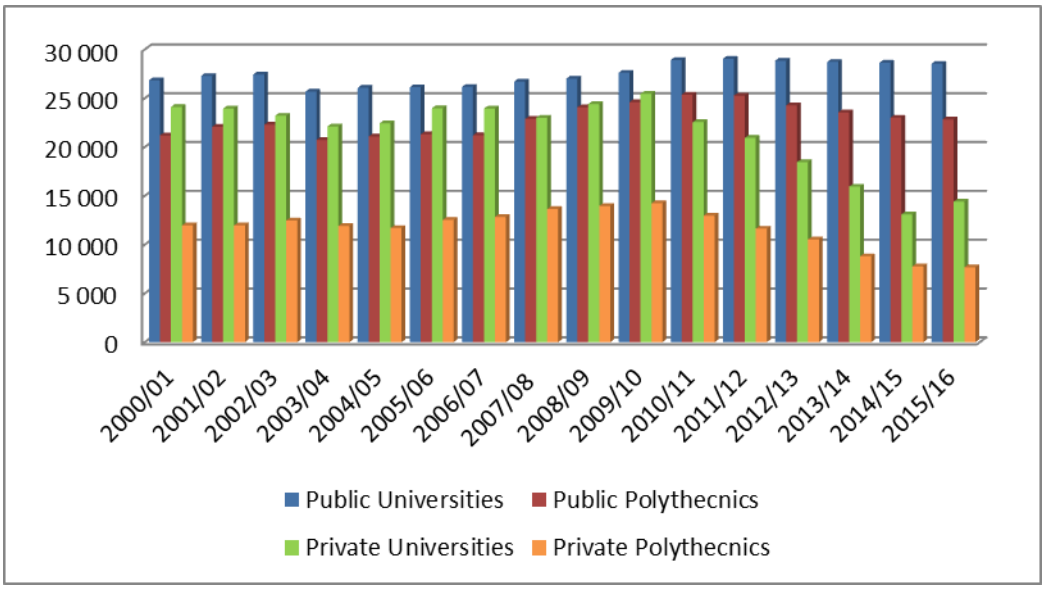
    - The National Competition is the one with the biggest percentage of enrolments to Public Higher Education, representing usually more than 75% of the total of students enrolled on the 1st year (for the 1st time) in the Public Higher Education Institutions (around 83% in the university institutions and 65% in the polytechnic institutions).

    - Access to private higher institutions is mainly achieved through Institutional competitions which are done with the responsibility of institutions. In 2014/2015, it represented about 58% of the new enrolments in these institutions (62.1% in private universities and 47.1% in private polytechnics).

    - To enrol in higher education through the National Competition, the Local Competition or Institutional Competition students must have finished upper secondary school and have a minimum grades of 95/200 in the national examinations in the specific study fields that are demanded for the HEI's for each course.

    - The number of vacancies available for the 1st cycle, that was 84130 in 2000/01 and reached a peak of 91901 in 2009/10, is now in the lowest point since the beginning of the century, with 73995 in 2016/17. In this year, the public sector (not including Universidade Aberta) accounts for 70% of the total number of vacancies provided. Public universities have 39% of the total vacancies and Public Polytechnics have 31%. Private universities have 20% of the total vacancies and Public Polytechnics have 10%.

Figure 2.3
Number of vacancies provided to enrol on 1st cycle, 2000/01 – 2015/16



Source: DGEEC. Note: In 2014/15, the vacancies of Universidade Católica are not included. This data should be reported on private universities. The university had around 2000 vacancies in that year.

- In 2016/17, a total of 113,915 students (almost more 10.000 students than in 2014/15) were enrolled in higher education institutions in the first year, for the first time, at all levels. 83.3% in public education (94929) and 16.6% in private education (18 986). Of the total number of students enrolled in the first year, 62.4% belonged to university higher education institutions and 37.5% to polytechnic higher education institutions.
- The recent recovery is mainly related with an increase in the number of students applying and enrolling through the National Competition and the new Higher Education Professional Technical Courses. In fact, between 2014/15 and 2016/17 TESP accounted for 10618 new enrollees.
- The number of students enrolled for the first time, in the first year, following the special competition for those students over 23 years of age has sharply decreased since 2010. In 2015/16, the number of enrolments following this special competition was 4680, more than half it was five years ago when were enrolled 10242 students.
- Continuing the trend observed since 1995/96, women enrolled in 2016/17, in the first year, for the first time, continued to have the greatest weight in the total number of enrolled students in the first year, for the first time (55%, i.e., 62 956 students)

3. Student enrolment in higher education

- The number of students currently in tertiary education is important because it determines, in part, a region's future competitiveness in terms of its ability to promote technological change and to create value. It is obvious that the rise in level qualification of the young Portuguese population is associated with the fact that the Portuguese tertiary education system grew rapidly in the 1980s and 1990s and opened up to young people of all social classes, growing from 30,000 students in the 1960s to about 400,000 students by the mid-2000s.
- Although Portugal still remains one of the OECD's country with less social mobility, with the children of families whose parents have higher education being 5 times more likely to access to higher education than the others, we should remember that in the mid-60s, the opportunity of access to higher education for students whose one parent had a higher education degree was 488 times higher that of other students.
- That is noticed in the tertiary education participation of 20-year-olds. The number of students in that age has increased by 16% over the last 10 years, reaching about 40% of this age-group in 2015, as compared to 30% in 2005. However, the schooling rates in higher education in the other reference ages have been falling since 2010.

Table 2.2
Enrolled students aged 20 as a percentage of corresponding age population

	2006/07	2010/11	2016/17 (p)
Students enrolled - 20 years old	37 430	44 495	45 927
Population - 20 years old	120 264	116 984	108 253
%	31,10%	38,00%	42,43%

Source: DGEEC/INE

- After a period of great expansion, the tertiary system has been shrinking since 2010, due to the effects of the negative evolution of demographic rates but also to the economic crisis that was felt in Portugal in the last few years. In fact, with higher rates of unemployment between general population also affecting graduates, the expectations regarding the advantages of holding a higher qualification fell down in these years. Despite the public and private benefits resulting from completion of a degree, the increase in the unemployment rate of graduates contributed to reduce the social expectations about the added value of higher education.
- However, the negative trend of enrolments appears to be starting to change, namely:
  - The number of new students enrolled on the Higher Education Professional Technical Courses (TESP), short cycle corresponding to the level 5 of the European Qualifications Framework and totally professional oriented, is sharply rising);
  - The national competition to entry higher education (the main entry route in Higher Education) has been rising in the last three years, after being falling since 2010
- In the school year 2016/17 there were 361 943 students (with mobility) enrolled at all levels of higher education. Most tertiary education students were enrolled in public establishments, which accounted for 83.6% of students enrolled. 65% of the students were enrolled at universities (public and private) and 35% in polytechnics (public and private)
- The representation of women in higher education institutions was 53.3% (194 024 female students), which has remained the same since the 2007/08 school year.

Table 2.3
Students enrolled in higher education institutions by nature of institution (1995/96 - 2016/17)

Nature of institution		1995/96	2000/01	2005/06	2010/11	2016/17
Public Higher Education	University	139 101	171 735	171 575	193 106	192 201
	Polytechnic	59 673	101 795	103 946	114 872	110 395
	Total	198 774	273 530	275 521	307 978	302 596
Private Higher Education	University	89 744	81 544	61 197	60 452	43 013
	Polytechnic	24 897	32 629	30 594	27 838	16 334
	Total	114 641	114 173	91 791	88 290	59 347
Subtotal	University	228 845	253 279	232 772	253 558	235 214
	Polytechnic	84 570	134 424	134 540	142 710	126 729
	Total	313 415	387 703	367 312	396 268	361 943
Students enrolled in Technological Specialization Courses						
Public Higher Education	Total	-	-	1 017	6 054	-
Private Higher Education	Total	-	-	242	1 123	-
Subtotal	Total	-	-	1 259	7 177	-
TOTAL		**313 415**	**387 703**	**368 571**	**403 445**	**361943**

Source:DGEEC

4. Higher education graduates and employment rates

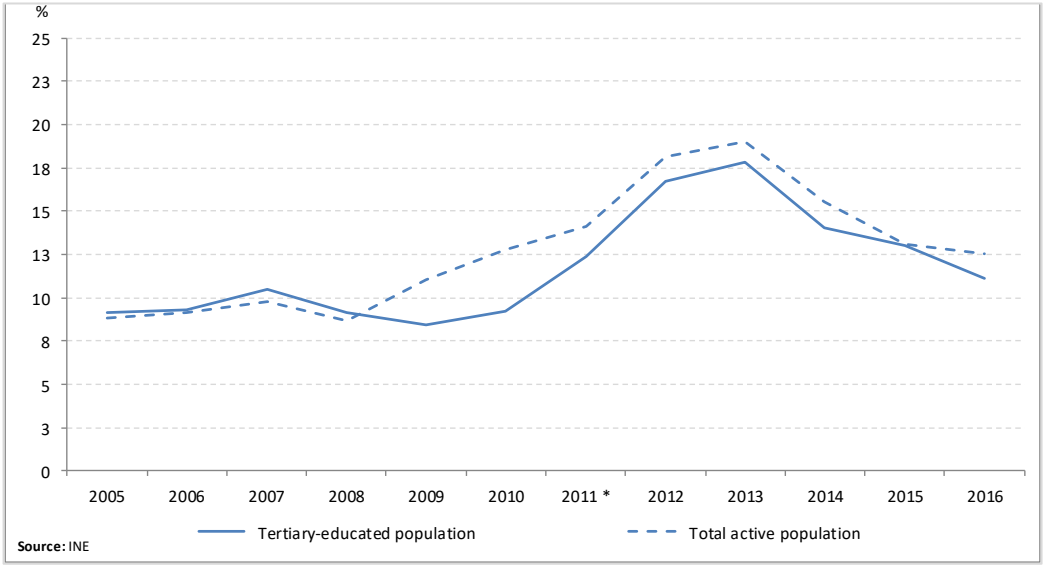
- After a period when the total number of graduates from higher education institutions increased by about 21% (period 2005-2011), the number of graduates kept stable since then.
- The number of graduates increased by 46.3% in the past 14 years (61.1 thousand in 2000/01, against 89.5 thousand in 2014/15), and their performance improved, as assessed by their share vis-à-vis the number of students enrolled, which in the same period increased from 15.8% to 25.6%.
- There were 89.5 thousand graduates in 2014/2015, accounting for a 1.1% increase from the previous school year. The field of study with the highest number of graduates was Social Sciences (31,1% of graduates), followed by engineering and engineering trades (18,4%).
- In 2014/15, HEI's awarded 94 537 diplomas (89476 related with higher education courses and 5061 regarding Technical Specialization Courses) of which 83.0% in public education (78 439) and 17.0% in private education (16 098). Compared to 2013/14, there was a 2.4% increase in the number of diplomas awarded on public higher education, while in private higher education there was a decrease of 2.0%.
- The representation of female graduates was of 58.6% (55 357), having fluctuated between 58.4% and 59.7% since the 2007/08 school year.
- In 2014/15, about half of the graduates, 49.9%, obtained a degree at the undergraduate level (Licenciatura) and 8.6% of the total had attained an integrated master (Mestrado Integrado). The number of diplomas in master's degrees (16 746) accounted for 17.7%. The number of diplomas in doctoral programs (2 351) represented 2.5% of the total diplomas.
- Compared to 2000/2001 the number of graduates went up by 46.3%. This considerable rise was accompanied by a change in the relative importance of the different fields of study. In 2000/2001 most graduates were found in teacher training and education science (19.7%), compared to 8.0% in 2014/2015 (40.8% decline in the number of graduates).
- Business and administration ranked second, at 18.1%, and since then the number of graduates has increased by 21.0%. The relative importance of health was close to the current level (14.9%), and the number of graduates increased by 54.3%. Engineering and engineering trades was the field of study which increased the most in terms of the number of graduates vis-à-vis 2000/2001, i.e. from 6.4% to 12.4% (181.1% increase).

Figure 2.4
Employment rates of 25-34 years old

The values were calibrated using the population estimates calculated from the final results of Census 2011.
Available flags: * A new data series of the Labor Force Survey was initiated in 2011 and direct comparisons with estimates from the previous series (effective 1998 to 2010) are not possible.

- The employability rates of graduates aged between 20 and 34 has been declining since 2008, not only in Portugal but also in Europe. Despite this, it turns out that holders of an academic degree have the highest rates of employability. It is also observed that the degradation of employability that occurred since 2008 was more pronounced in the case of less educated citizens.
- The figure below also shows that the tertiary-educated population still has higher employment rates, in Portugal, than the global population. The gap has been narrowing though.
- The unemployment rate is the ratio between the unemployed population and the active population. Again considering the age group 25-34, the graphic below shows that the unemployment rate has had, in Portugal, behaviour roughly inverse to the behaviour of the employment rate, as expected. So we observe a general increase in unemployment during the years leading up to 2013, followed by an equally clear fall in unemployment, which continues up to the present.
- It is interesting to observe that the premium of higher education seems to be less clear when one considers unemployment rates, rather than employment rates. The graphic shows several years since 2005 where unemployment rates of tertiary-educated are very close to, and even above, unemployment rates of the global population. This apparent paradox can be explained by the observation that the active population represents a larger share of the resident population for the tertiary-educated than for the general population.

Figure 2.5
Unemployment rates of 25-34 years old



The values were calibrated using the population estimates calculated from the final results of Census 2011.
Available flags: * A new data series of the Labor Force Survey was initiated in 2011 and direct comparisons with estimates from the previous series (effective 1998 to 2010) are not possible.

- The total active population, aged 25-34, has steadily decreased in Portugal over the last 10 years. This is mostly due to a decline of the resident population in that age group. Nonetheless, the active population with tertiary education has clearly increased, which shows that the higher qualifications of the younger age cohorts have more than compensated their declining overall numbers.
- The average gain of workers with bachelor's degree equivalent to 1.7 times the global average and that of workers with a doctorate of 2.2 times. At the other extreme, the gain the average number of workers with a level of qualification 1st cycle of basic education corresponded to 62.7% of the average gain global.

5. Internationalization of Higher Education

The Government recently approved a set of general guidelines for the articulation of the policy of internationalization of higher education, science and technology with the other public policies of internationalization. In that decision (Minister Council Decision n. º78/2016) the main guidelines that were approved, among others, were:

i. To promote "Study in Portugal" and "Research in Portugal" initiatives and participation in international students recruitment fairs;

ii. To develop multilingual information material about courses and training on HEI;

iii. To make simpler visa procedures for international students;

iv. To offer scholarships and internships for incoming students and trainees;

v. To promote internationally the national network of scientific infrastructure, especially among the Portuguese speaking countries;

vi. To launch the programme "Ciência Global" and prioritization of the Cooperation with Portuguese-Speaking African Countries and Timor-Leste;

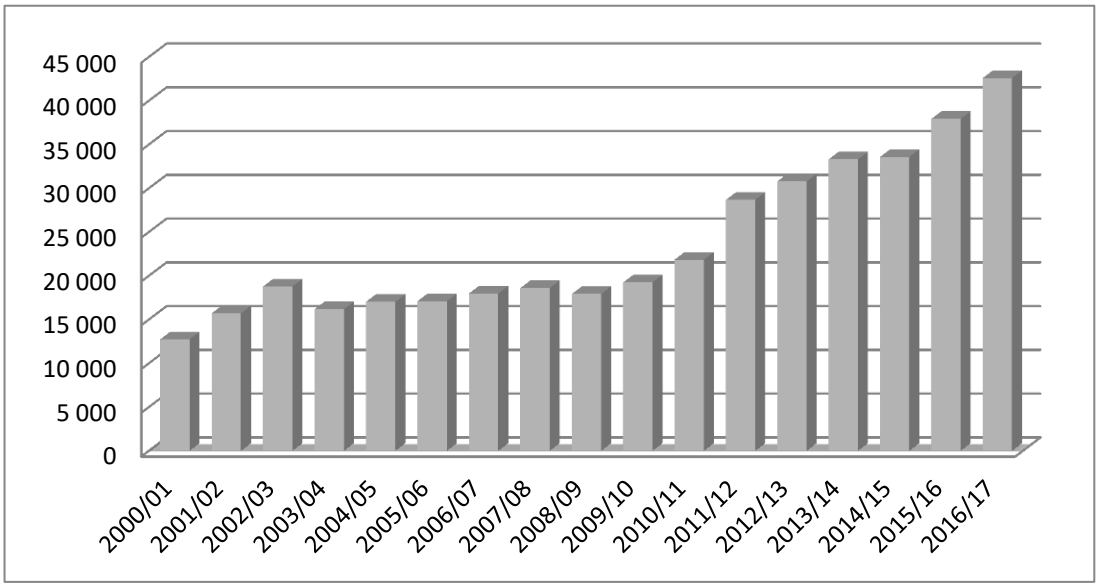
vii. To promote the Portuguese participation on INL, CERN, ESA, EMBL and ESO;

viii. To develop the programme «SPYDER Portugal», that stands for "Stimulating Processes for Innovation and Development based on Research networks";

ix. To promote scientific diplomacy, through the appointment of scientific advisors on Embassies, the promotion of HEI and scientific system in each embassy activity plans and the implementation of an Advanced Seminar on Scientific and Technological Policies headed to diplomatic representatives.

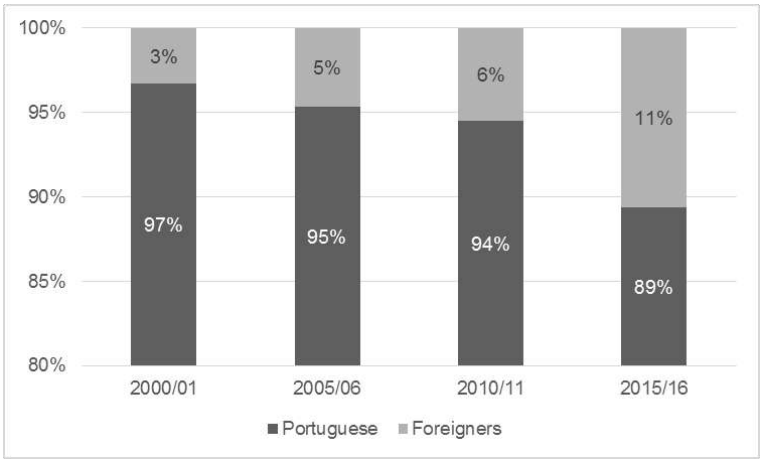
- The number of foreigner students has been steadily increasing in the last decade. In fact, the number more than doubled since 2008, what is related with the growth of mobility but also the higher enrolment rates from students that come do their entire course in Portugal and are nationals from non-European countries.

Figure 2.6
Foreigner students (including mobility) enrolled in HEI, 2000/01-2016/17



Source: DGEEC

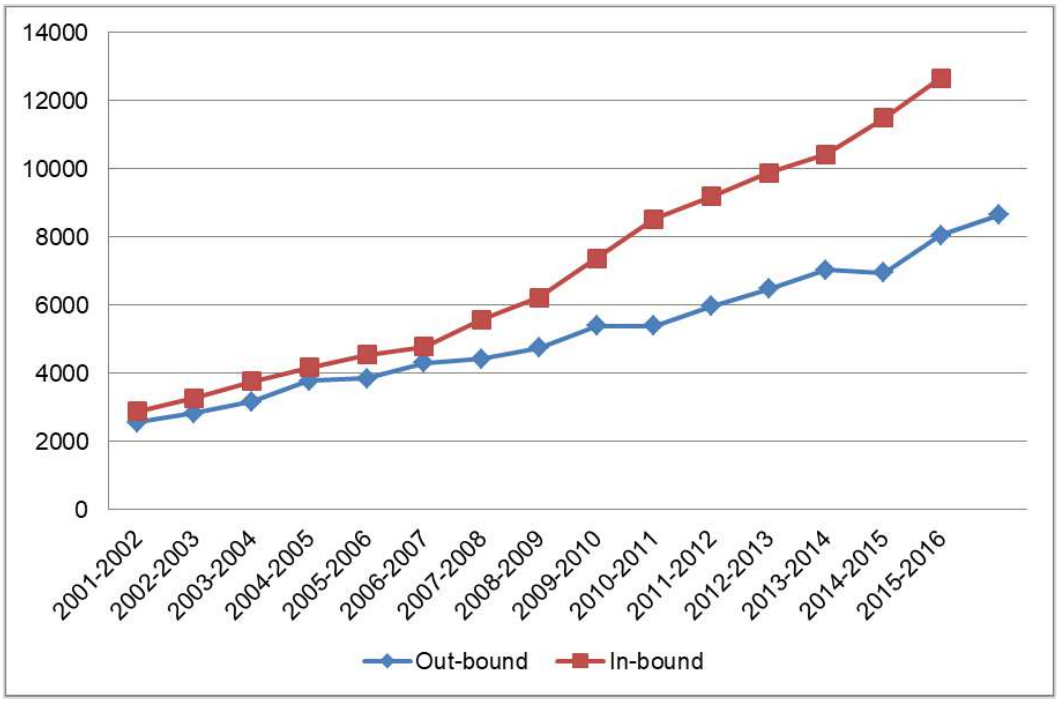
Figure 2.7
Portuguese and foreigner students (including mobility) enrolled in HE, %



Source: DGEEC

- Since 1987, the Erasmus programme funded outgoing mobility for more than 100,000 Higher Education students and more than 15,000 Higher Education staff from Portugal. However, Portugal always received more Erasmus students and staff from other Programme countries, than sent Portuguese Erasmus students and staff abroad.
- The ratio of incoming/ outgoing student mobility was always positive, but it increased significantly since the academic year 2009/2010, when the number of incoming students was 37% above the number of outgoing students, and it has remained above 40% since the academic year of 2010/2011.

Figure 2.8
Incoming and outgoing student mobility flows, 2000-2016



Source: Erasmus + (Education and Training) National Agency

- Portugal hosts Erasmus students from all over Europe, either for studies or internships, usually figuring among the top 10 country receivers every year, but the main sending countries are Spain (26%), Italy (14%) and Poland (13%). Between 2007 and 2014, Portuguese Higher Education Institutions (HEI) and companies hosted more than 68,000 students

- .The differential between outgoing and incoming Erasmus students is mostly explained by the fact that Portugal receives students from over 30 countries. However, Portugal is among the most popular countries for Erasmus, which may be explained by the cost of living and HEI with good quality, among other factors.
- Over half of the student mobility and most staff mobility took place since 2007: the Portuguese Erasmus programme funded more than 65,000 outgoing students and 11,000 outgoing staff in the period 2007-2016. While student mobility started in 1987, Higher Education teacher mobility only started in 2000, and other Higher Education staff mobility started in 2007.

6. HEI's and Courses

- The Portuguese higher education system includes public higher education, made up of institutions belonging to the State and the university foundations instituted by it, and private higher education, consisting of institutions belonging to private entities and cooperatives. Public Higher education institutions have a high level of autonomy, especially the university foundations that were created after the last OECD Review.
- The regional distribution of higher education in Portugal essentially copies the national urban landscape. The Public Institutions cover the entire national territory, introducing a more dispersed pattern than the Private Institutions that are concentrated in the metropolitan areas of Lisbon and Porto and in the regions with greater population.
- Public polytechnics are the HEI's that are more spread throughout the country, being present in 47 different municipalities. Public Universities are present in 16 municipalities. Private universities are present in 13 municipalities and private polytechnics in 28. Although the network is spread, the municipalities of Lisbon and Porto concentrate a vast number of public and private institutions, courses and students enrolled.

Table 2.4
Higher Education Institutions (including organic units), by NUTS II, 2016/17

		Universities			Polytechnics		
	Total	Total	Public	Private	Total	Public	Private
Portugal	**286**	**121**	**79**	**42**	**165**	**101**	**64**
Norte	**98**	40	19	21	58	27	31
Centro	**54**	17	12	5	37	32	5
A.M. Lisboa	**90**	50	35	15	40	17	23
Alentejo	**20**	4	4	-	16	14	2
Algarve	**11**	5	4	1	6	5	1
R.A. Açores	**8**	**4**	**4**	**-**	**4**	**4**	**-**
R.A. Madeira	**5**	**1**	**1**	**-**	**4**	**2**	**2**

Source: DGEEC

- Following the last OECD and ENQA reviews, developed in 2006, the Government decided to create the "Agência de Avaliação e Acreditação do Ensino Superior" (Agency for Assessment and Accreditation of Higher Education - A3ES), by Decree-Law no. 369/2007, of 5th November, with the purpose of promoting and ensuring the quality of higher education.
- The Agency is a private law foundation, established for an indeterminate period of time, with legal status and recognized as being of public utility. The Agency is independent in its decisions, which must take into account the guidelines prescribed by the State. The Agency initiated its activities in 2009, with that year being almost fully dedicated to the implementation of structures and procedures, appointment of the different governance bodies and hiring and training staff.
- The outcomes of the evaluation and accreditation procedures defined after 2009 are very relevant and also underline the efforts made by higher education institutions in the reorganization of their educational portfolio. The process of accrediting study cycles led to a decrease of 1049 degree programmes, as compared to those previously registered at the Directorate-General of Higher Education, representing a decrease of 20% in the number of courses.

Table 2.5
Number and type of Tertiary Education courses accredited, 2017

		Bachelor- 1st Cycle	Integrated Master	Master - 2nd cycle	PhD - 3rd cycle
Public HEI	Universities	528	112	1446	666
	Polytechnics	701	-	699	-
Military and Police HEI	Universities	-	26	9	-
	Polytechnics	13	-	-	-
Private HEI	Universities	350	29	425	73
	Polytechnics	281	-	188	-

Source: Directorate-General for Higher Education. TESP not included.

Table 2.6
Number of TESP courses and vacancies by year and type of HEI

Registered Courses *				**Available vacancies ***			
2014	**2015**	**2016**	**2017**	**2014**	**2015**	**2016**	**2017**
42	382	428	473	1446	12570	14225	15386
52	124	168	196	1595	3463	4716	5343
94	**506**	**596**	**669**	**3041**	**16033**	**18941**	**20729**

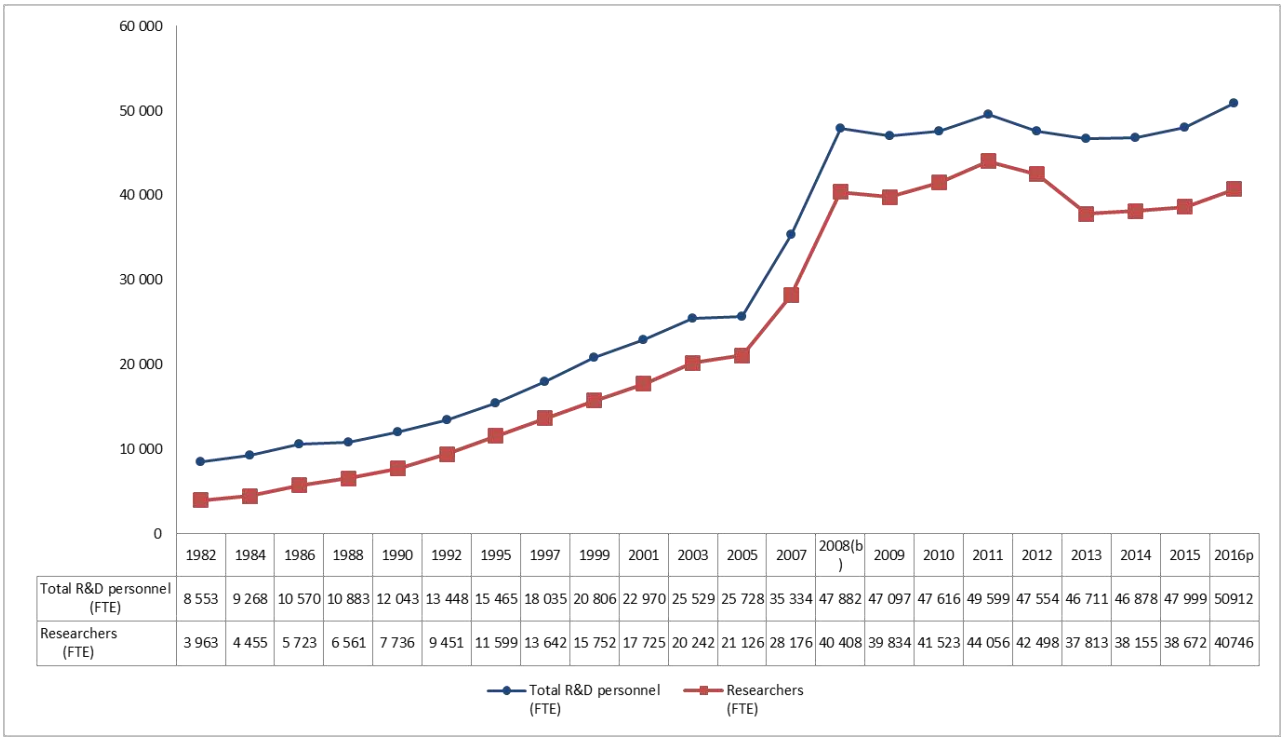
Source: Directorate-General for Higher Education. * Cumulative values

B. Science and Technology: the evolution of R&D capacity and innovation performance

1. Human resources in S&T

- The number of full time equivalent researchers in Portugal in 2016 (p) was 40746 (what represented about 7,9 per thousand workforce in the same year). This number represents a cutback in the figures that Portugal had in 2015, when the number of full time equivalent researchers was 38672 but is still below the 44056 researchers (FTE) registered in 2010.
- The total R&D personnel was 50912 (measured in FTE) in 2016 (p), also growing when compared with 2015.

Figure 2.9
Total R&D personnel and total researchers (as measured in "full time equivalent", FTE) in Portugal

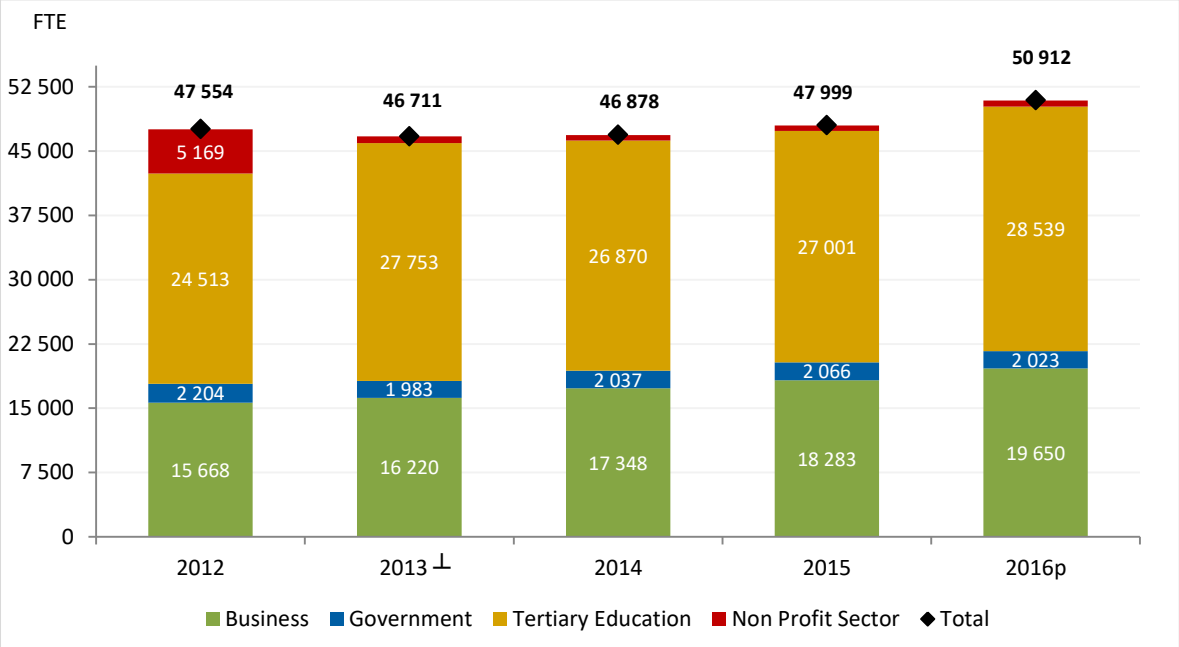


	1982	1984	1986	1988	1990	1992	1995	1997	1999	2001	2003	2005	2007	2008(b)	2009	2010	2011	2012	2013	2014	2015	2016p
Total R&D personnel (FTE)	8 553	9 268	10 570	10 883	12 043	13 448	15 465	18 035	20 806	22 970	25 529	25 728	35 334	47 882	47 097	47 616	49 599	47 554	46 711	46 878	47 999	50912
Researchers (FTE)	3 963	4 455	5 723	6 561	7 736	9 451	11 599	13 642	15 752	17 725	20 242	21 126	28 176	40 408	39 834	41 523	44 056	42 498	37 813	38 155	38 672	40746

Source: DGEEC. Note: p – provisional.

- In 2016 (p), the researchers were concentrated mainly at Tertiary Education and Private non Profit sector, with 26956 FTE (representing 66.6% of the total researchers), followed by the business enterprise sector with 12490 researchers FTE (representing 31% of the total researchers) and growing when compared with 2015. Only 1301 researchers were in the Government sector in that year.
- This has been matched by a significant increase in the total number of R&D personnel in the business sector between 2005 and 2011, which tripled from 4,014 to 12,198 researchers (FTE) and having a reduction in the period 2012-2015. In 2016, the number of researchers FTE in this sector grew to his highest number and representing about 2.4 per thousand workforce.

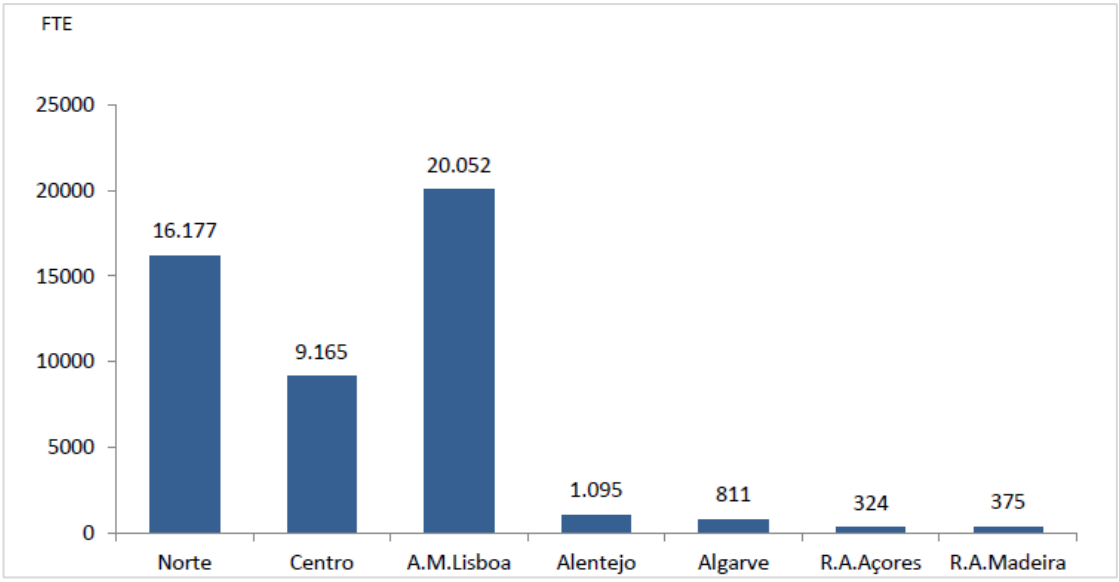
Figure 2.10
Total Staff in R&D (FTE), 2012 a 2016 (p)



Source: DGEEC, p – provisional

- In spite of the steep rise in the number of R&D personnel as a proportion of total employment throughout all Portuguese regions, there are still significant disparities between regions. In 2015, 42% of all the R&D personnel were concentrated in the Lisbon area, a share that has only fallen significantly in the last decade – from 53% in 2001 to 42% in 2015. On the other side, in the North of Portugal, there was an increase from 24% in 2005 to 34% in 2015.

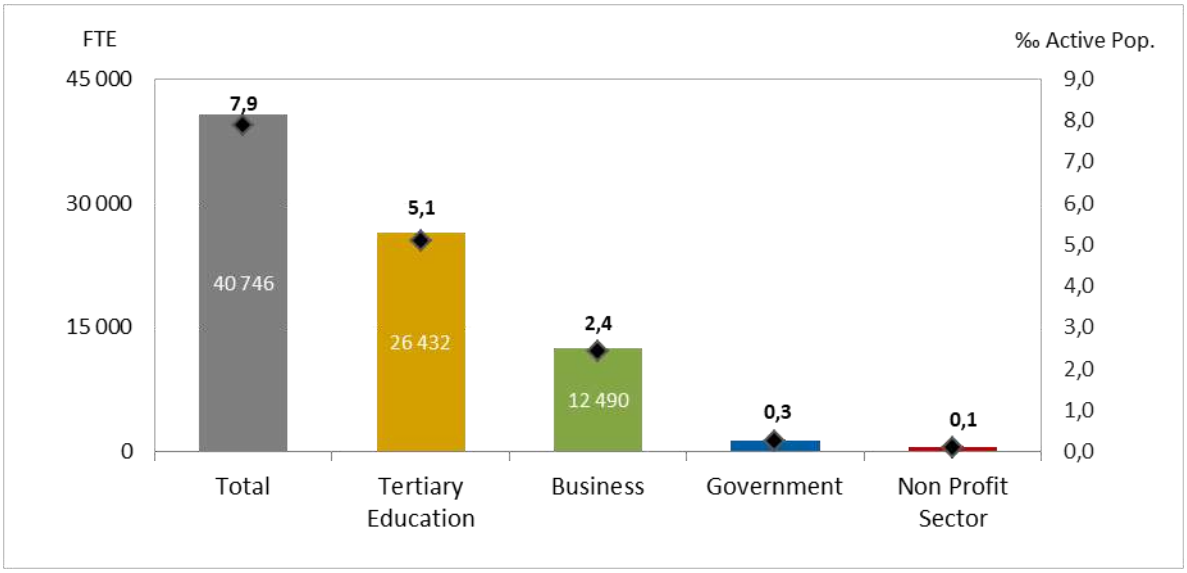
Figure 2.11
Total staff in R&D, by region (NUTSII), 2015



Source: DGEEC.

- The total number of researchers has increased about 9-fold since the early 1980s, from 0.9 per thousand workforce in 1982 (i.e., about 4,000 researchers FTE) to 7.9 in 2016. Taking into account the distribution by scientific or technological area, the last available data (2015) shows that 39% of the researchers were working the area of engineering sciences and technologies, followed by the area of exact sciences and social sciences, both with 14%. The medical and health sciences and the natural sciences had a very close percentage representation, 12% and 10% respectively.

Figure 2.12
Researchers in 2016 (p), FTE and per thousand inhabitants



Source: DGEEC, p – provisional

Source: DGEEC

1.1. Support to PhD students

- Portugal has made a remarkable investment in the training of advanced human resources in science and technology, through the continuous implementation of different support schemes.
- The PhD scholarships supported by the Foundation for Science and Technology (FCT) have averaged over 1000 grants per year since 2000, but have seen a significant decrease since 2007 (reaching a peak of 2030 in 2007 and a low of 685 in 2013). This decrease has been particularly significant following the onset of the global financial crisis, which also impacted the public investment on R&D programmes, more widely. After 2015, the number of PhD scholarships supported by the FCT starting recovering and in 2017 more than doubled when compared with 2013
- The support to PhD training has favoured the quality of the proposals, and has initially strongly endorsed training abroad. In 2000 less than 50% of the PhD scholarships were awarded for a full training program in Portugal. One third was for training abroad, and the remaining for mixed programs, typically with a degree awarded in Portugal and significant research stays abroad. With the increasing capacity of the local academic staff, PhD applicants have increasingly sought PhD training in Portugal – in 2015 this corresponded to two-thirds of the scholarships awarded, with the remaining being mostly mixed programs, and full training abroad being residual.
- No specific conditions are placed in this regard in the application process, but it reflects the fact that local host conditions are considered competitive in evaluation process and also by applicants. More generally this policy of openness has contributed to the development of a highly internationalised research community, for whom the initial PhD training has a significant international component that remains throughout career trajectories and that is reflected in the wider internationalisation of the system.

Figure 2.13
N. º PhD scholarships awarded by FCT, 2006-2017

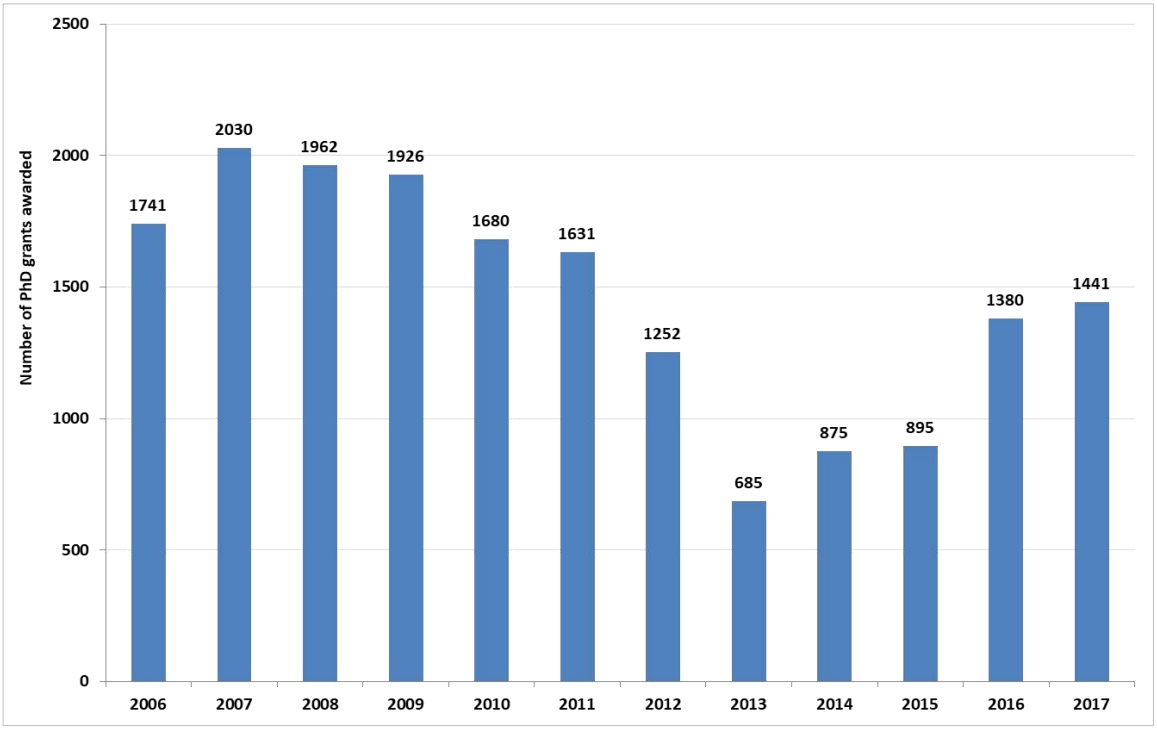
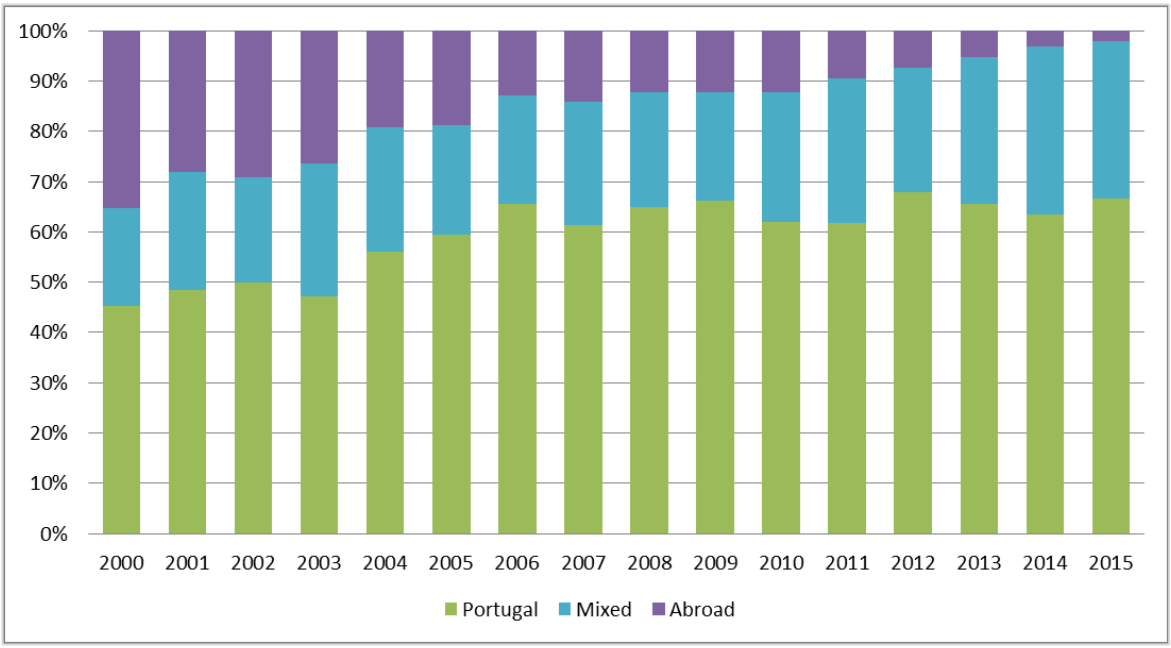


Figure 2.14
PhD Scholarships awarded by FCT, in Portugal, mixed or abroad, 2000-2015

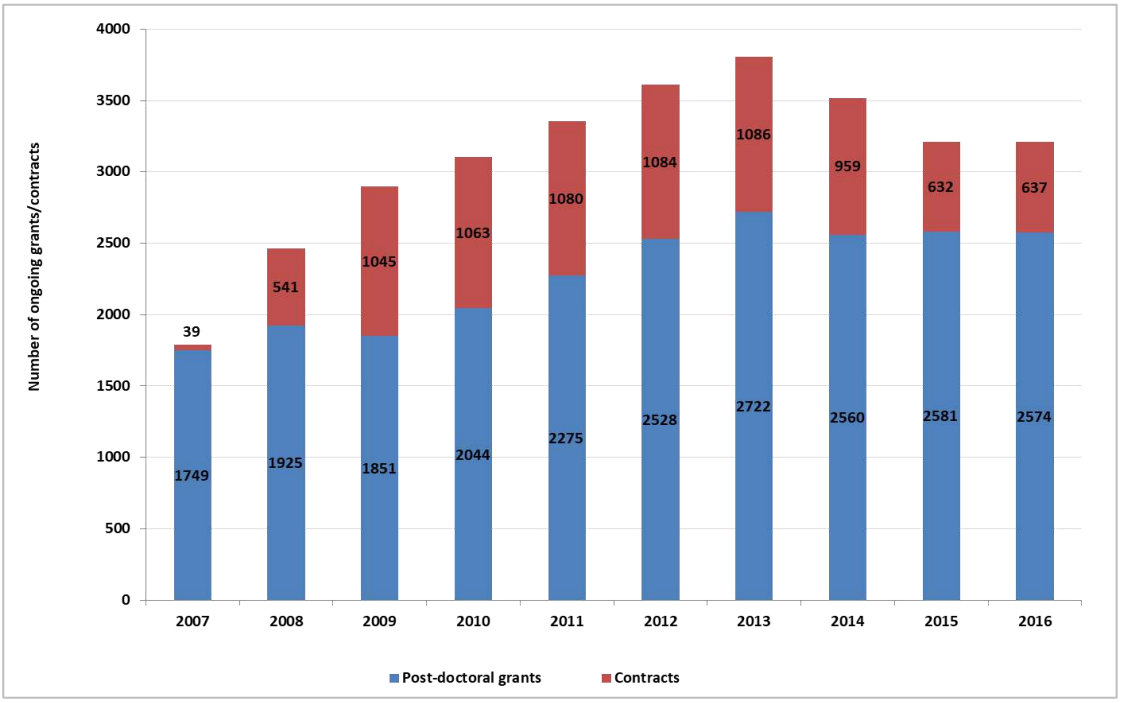


Source: FCT

1.2. Support to Post-Doctoral researchers

- As a result of the continued support to advanced training the number of PhD holders in Portugal has increased almost four-fold since the beginning of the century. With over 2500 new PhDs per year reached in 2013, the Portuguese system has been able to reach over 35.000 PhDs awarded or recognized in Portugal at present. This significant investment has represented a strong upgrade of the research and innovation system, largely led by public investment. Nevertheless, significant challenges remain regarding the development of stable research careers.

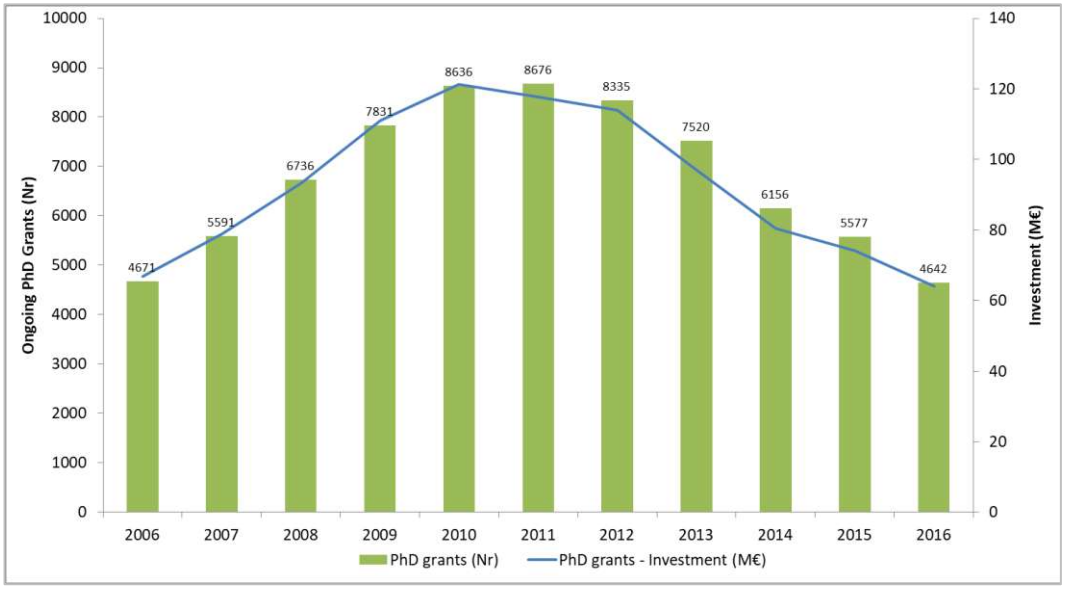
Figure 2.14
Evolution of PhD holders contracts and post-doctoral grants (2007-2016)



Source: FCT

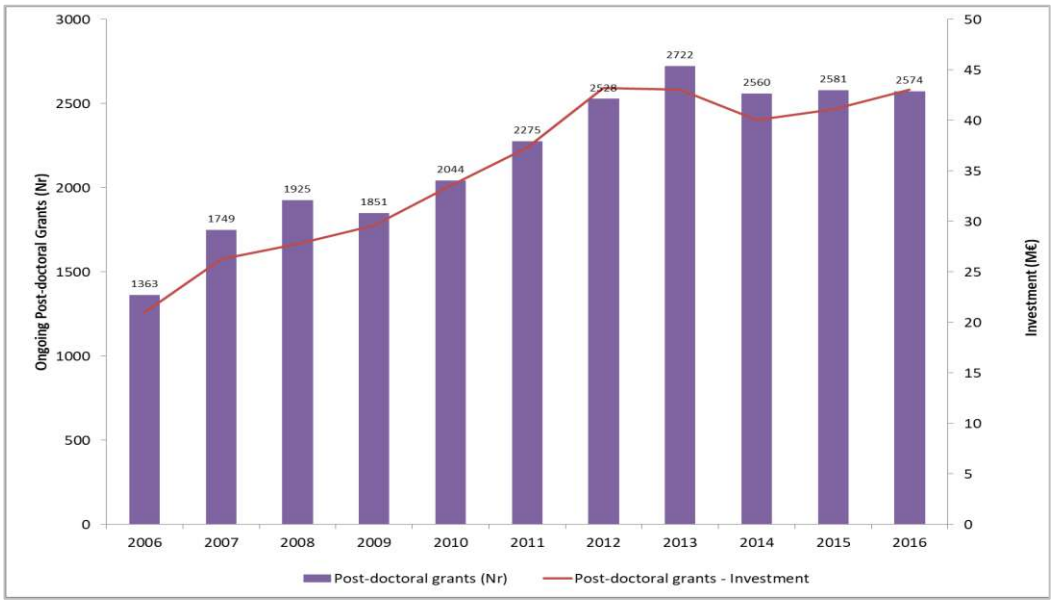
- In this way, FCT has also supported the development of research career trajectories through a number of schemes, either indirectly, through project grants that lead to research opportunities for PhD holders, or directly, through dedicated funding schemes to support post-doctoral or employment opportunities.
- The Post-Doctoral scholarships program, through a national call, which has been run in parallel (until recently) with the national call for individual PhD scholarships, has supported on average 500 post-docs per year, since 2000, through highly competitive calls.
- As in PhD scholarships, the number of post-doc scholarships awarded rose until 2006 to slightly over 700, but has decreased less significantly in recent years. In the last call, the number of post-doc scholarships decreased to 400, reflecting a new strategy for scientific employment in Portugal (the 2017 call was opened to PhD candidates only, thus not considering post-doctoral scholarships). With a maximum of 6 year duration (two 3-year periods) this support corresponds to circa 2500 post-doc researchers currently funded by FCT.

Figure 2.15
Evolution of ongoing PhD grants and Investment (2006-2016)



Source: FCT

Figure 2.16
Evolution of ongoing Post-Doctoral grants and Investment (2006-2016



Source: FCT

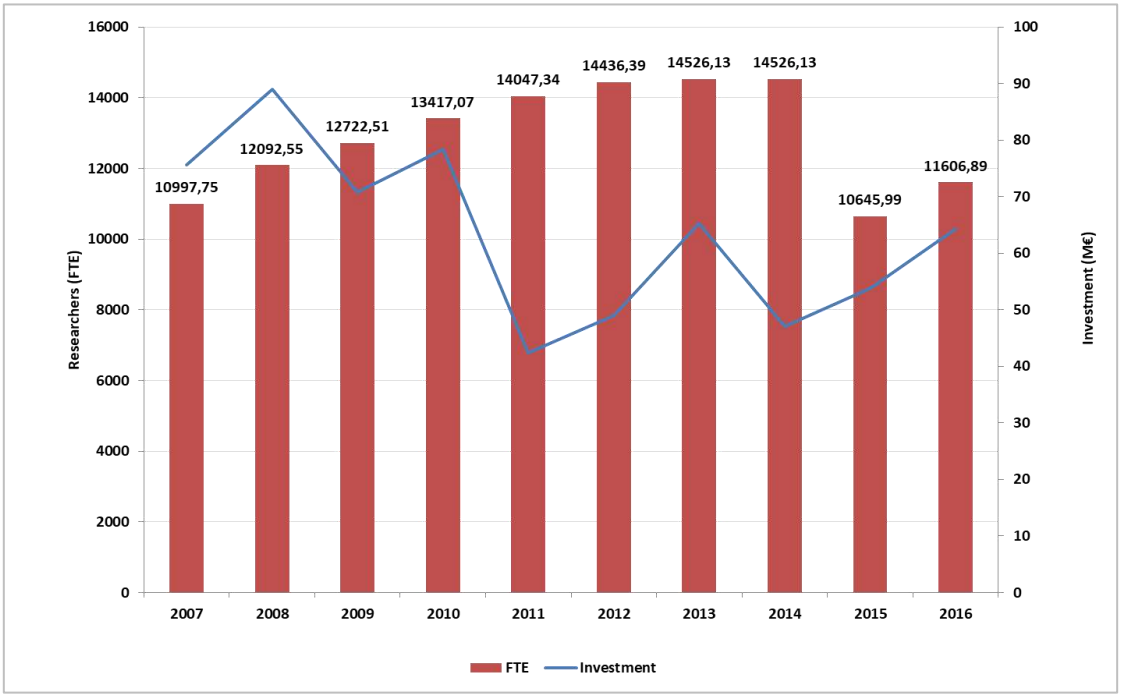
- As previously mentioned, there is being putted in place a new program to foster scientific employment and access to research careers. The overall Program includes the following 8 lines of action for the period 2017-2019 (3 years of investment), covering a total of 5000 expected research doctorate contracts to be awarded:
    - Individual doctorate research contracts in research and academic institutions, in public open competitions to be offered through FCT for individual doctorates;
    - Institutional employment and research career development plans, in public open competitions to be offered through FCT for institutions;
    - Institutional recruitment and career development plans, with public open competitions to be offered directly through the institutions;

- Individual doctorate research contracts through FCT funded R&D projects, in public open competitions to be offered through FCT for R&D projects, with the need to offer a doctorate research contract;
- Individual doctorate research contracts in research and academic institutions to be funded by FCT through the transition regime for the new legal regime of scientific employment (DL 57/2016), with public open competitions to be offered through institutions for individual doctorates;
- Individual doctorate research contracts through Collaborative Laboratories, with Public open competitions to be offered through PT2020 for establishing Collaborative Laboratories, with the need to offer doctorate research contracts;
- Individual doctorate research contracts through European co-funding mechanism;
- Fiscal incentives for the employment of doctorates by the business sector (i.e., SIFIDE)

1.3. R&D Units

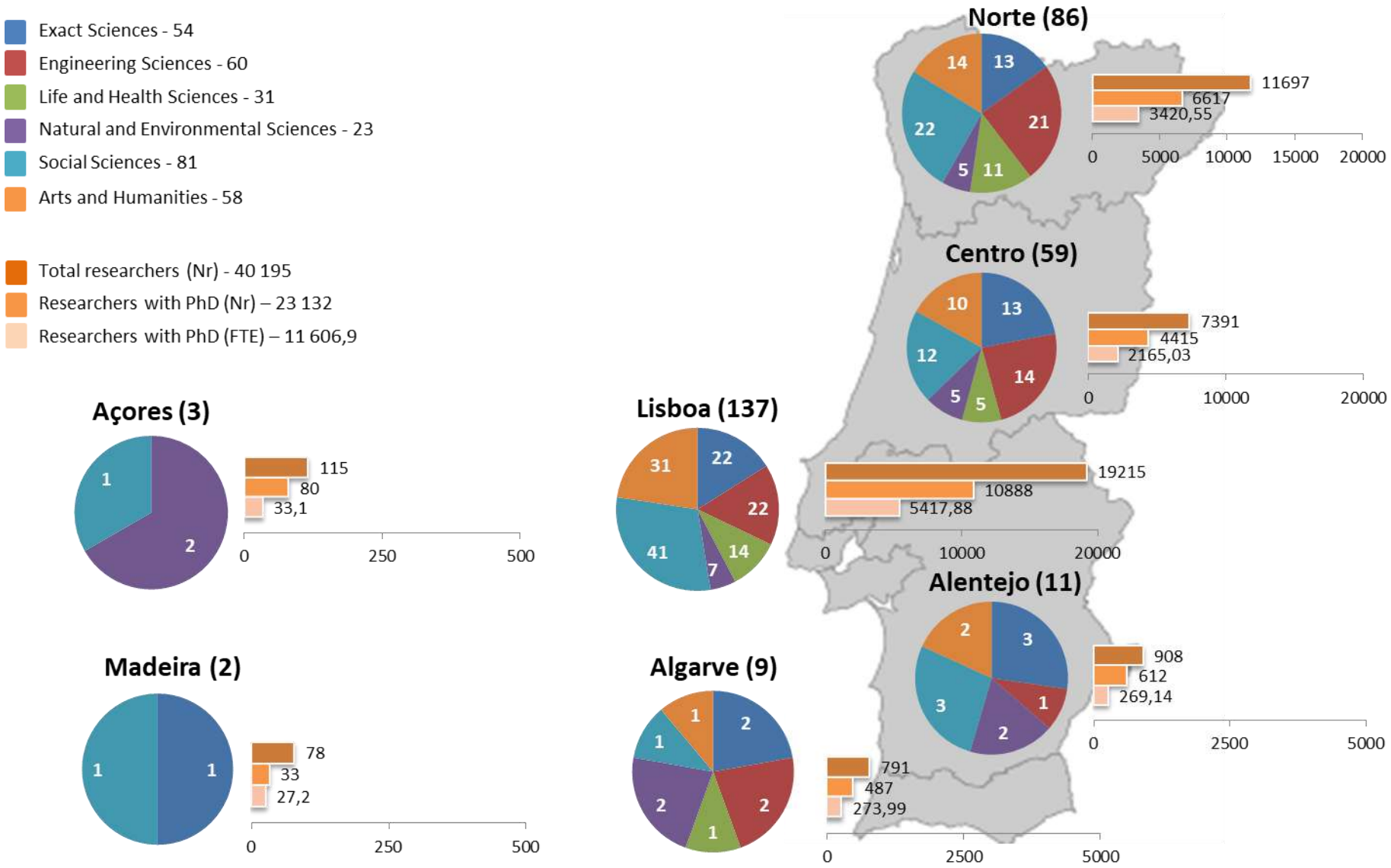
- The birth and development of R&D units was first made in Portugal outside Higher Education Institutions and only in the last decade the relationship between R&D units and HEI was more intensified. That was due to the fact that University administration in the 80s was very dominated by a bureaucratic culture which was in contradiction with the dynamic and versatile culture of the research environment. In fact, it was not only a contradiction but constituted a severe obstacle to intellectual creativity and to the internationalization making very difficult to do good research, by international standards, frustrating the most talented researchers.
- This fact has led groups of researchers, in articulation with higher education institutions and companies, to create private non-profit institutions in order to facilitate institutional flexibility in contracting with the outside and attracting human resources. This together with the regular evaluation exercises conducted by FCT, the publication by the state of Decree-Law 125/99 and the creation of the Associate Laboratories based on scientific evaluation, in order to foster critical mass, aggregating various R & D groups and attracting new talents has contributed to a unprecedented development and internationalization of the National scientific System.
- Most of the Portuguese scientific research is carried out in R & D Units and Associated Laboratories, financed and evaluated by FCT, with the only exception of the evaluation conducted in 2013 where FCT has delegated his evaluation responsibility in the ESF – European Science Foundation. There are currently 307 R & D Units with approximately 40.000 individuals and more 11000 researchers with PhD (FTE)
- Research carried out in these institutions covers all fields of science, from the life sciences and health to the social and human sciences, through engineering, exact sciences, natural sciences and the environment. Institutions are regularly evaluated by FCT and currently a new evaluation exercise is underway.

Figure 2.17
Evolution of R&D units researchers and funding (2007-2016)



Source: FCT. Note: Statistical break in 2015. Until 2014, a time allocation above 30% corresponded to 1 FTE From 2015 onwards, the FTE correspond to the effective portion of time devoted to research

Figure 2.18
R&D Units funded by FCT



Source: FCT. Note: The regional distribution map considers only the proposing institution (the whole team is assigned to the unit there), but the R&D units can also include centers in other regions.

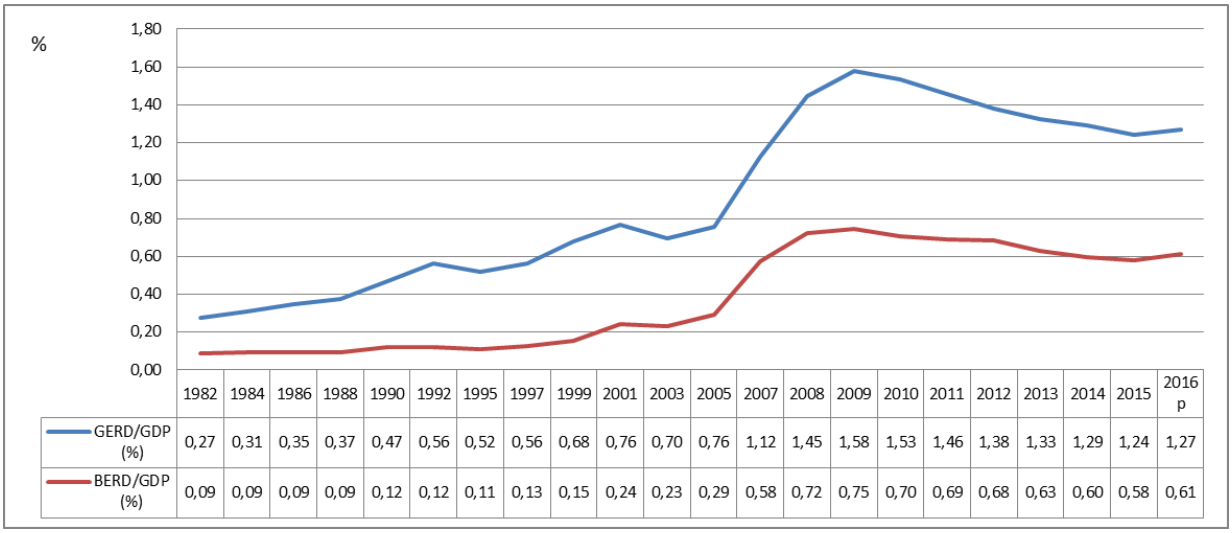
2. Funding of public higher education and research institutions

- The total income of public higher education institutions and research institutions, together with the overall funding for students´ social support, during the period (2011-2016), was influenced by the budget restrictive policies implemented by the Portuguese Government in 2011, which were reflected in salary cuts. Since the end of 2015, the wage reduction was progressively reverted and in the last quarter of 2016 the salaries had no more cuts.
- In the weight of total income of public higher education institutions and all research institutions, together with the overall funding for student´s social support on GPD varied over the period, reaching the highest value in 2013 (1,35%) and the lowest in 2016 (1,22%), strongly influenced by the transition between European framework.
- The total income of public higher education institutions and research institutions oscillated between 2 129 million Euros in 2011 to 2 121 million Euros in 2016, with the direct contribution from government funding for operation (i.e., salaries and other operating costs), achieving the highest value in 2013, accounting for about 2 175 million Euros.
- The diversification of income portfolio of public higher education institutions has been associated with funding for R&D activities, mainly with EU competitive structural funding and direct EU competitive funding, together with public funding for research institutions reached 816 million Euros in 2013 and decreased in the following years, down to 737 million Euros, which is the value accounted in 2016. Student tuition fees increased by over 8, 2% between 2011 and 2016 reaching 315 million Euros.
- The direct public funding to HEIs: social support services (i.e., catering services, accommodation and other student services) has been kept constant at about 28 million Euros and represent, on average, about 2,7% of the total public funding to HEI´s.

2.1. GERD & BERD

- Until 2010, the gross expenditure on research and development in Portugal was growing at one of the fastest rates observed in the OECD at the time. The total R&D expenditure as a percentage was 0.7% in 1999, 0.8% in 2005, 1.1% in 2007 and reached a peak of around 1.55% of GDP in 2009 and 2010. The growth that was taking place was due to a substantial accumulation of public investment in science and technology aiming at developing the national knowledge base, but also to the leverage of private investment in research and development.

Figure 2.19
Total and Business R&D expenditure as a percentage of GDP, 1982-2016p



	1982	1984	1986	1988	1990	1992	1995	1997	1999	2001	2003	2005	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 p
GERD/GDP (%)	0,27	0,31	0,35	0,37	0,47	0,56	0,52	0,56	0,68	0,76	0,70	0,76	1,12	1,45	1,58	1,53	1,46	1,38	1,33	1,29	1,24	1,27
BERD/GDP (%)	0,09	0,09	0,09	0,09	0,12	0,12	0,11	0,13	0,15	0,24	0,23	0,29	0,58	0,72	0,75	0,70	0,69	0,68	0,63	0,60	0,58	0,61

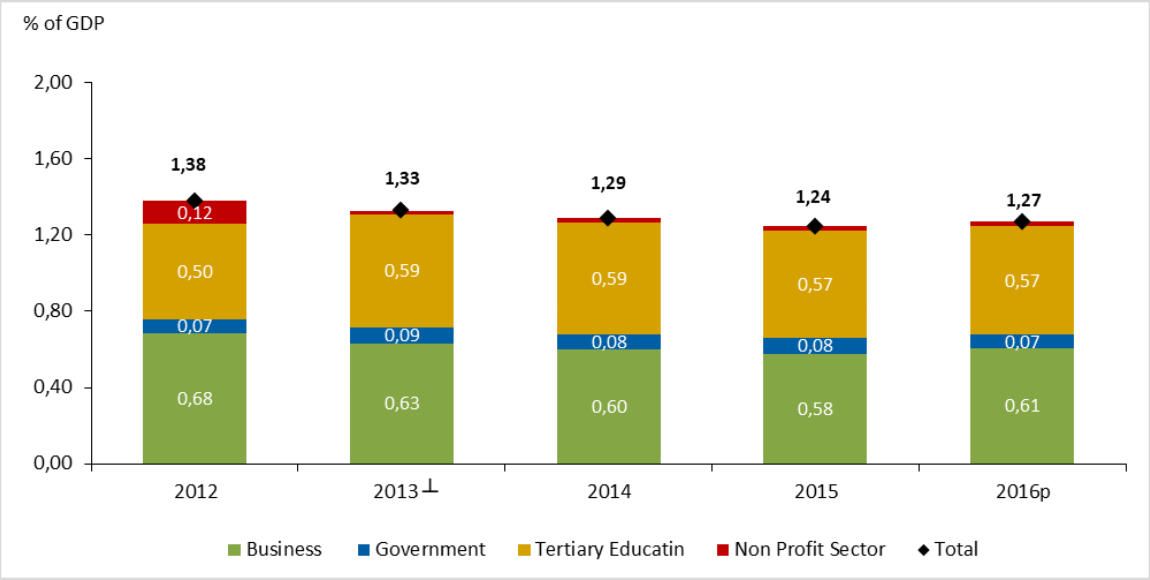
- The evolution of S & T investment in Portugal has become noteworthy at the end of the first decade of the 21st century, interrupting a past trend of relative slowness or intermittency on investment, and reaching unprecedented levels of development. In 2007. In 2009, Portugal surpassed several countries which historically invested more heavily in R & D than Portugal, such as Italy (1.19%), Ireland (1.43%) or Spain (1.35%). In this context, the total public R & D budget grew by 11% per year between 2004 and 2009, being among the highest percentages in Europe at that time.

Table 2.7
Gross Domestic Expenditure in R&D, by sector, 2001-2016 (p)

	Total	Business Enterprises		Government		Higher Education		Private non Profit	
	Million Euros	Million Euros	%	Million Euros	%	Million Euros	%	Million Euros	%
2001	1 038,4 €	330,3 €	32%	215,5 €	21%	380,6 €	37%	112,0 €	11%
2003	1 019,6 €	338,0 €	33%	172,0 €	17%	391,8 €	38%	117,7 €	12%
2005	1 201,1 €	462,0 €	38%	175,6 €	15%	425,2 €	35%	138,4 €	12%
2007(a)	1 972,7 €	1 010,8 €	51%	184,5 €	9%	587,0 €	30%	190,5 €	10%
2008(b)	2 585,1 €	1 295,1 €	50%	188,3 €	7%	891,3 €	34%	210,4 €	8%
2009	2 771,6 €	1 311,1 €	47%	202,5 €	7%	1 013,7 €	37%	244,3 €	9%
2010	2 757,6 €	1 266,3 €	46%	196,3 €	7%	1 016,6 €	37%	278,3 €	10%
2011	2 566,4 €	1 216,3 €	47%	189,3 €	7%	933,8 €	36%	227,0 €	9%
2012	2 320,1 €	1 153,3 €	50%	124,2 €	5%	846,0 €	36%	196,6 €	8%
2013 (c)	2 258,5 €	1 072,9 €	48%	147,2 €	7%	1 008,3 €	45%	30,1 €	1%
2014	2 232,2 €	1 036,0 €	46%	139,8 €	6%	1 018,0 €	46%	38,4 €	2%
2015	2 234,4 €	1 036,5 €	46%	144,9 €	7%	1 017,6 €	46%	35,4 €	2%
2016 (p)	2 347,7 €	1 123,2 €	48%	126,6 €	5%	1 059,3 €	45%	38,6 €	2%

Source: DGEEC

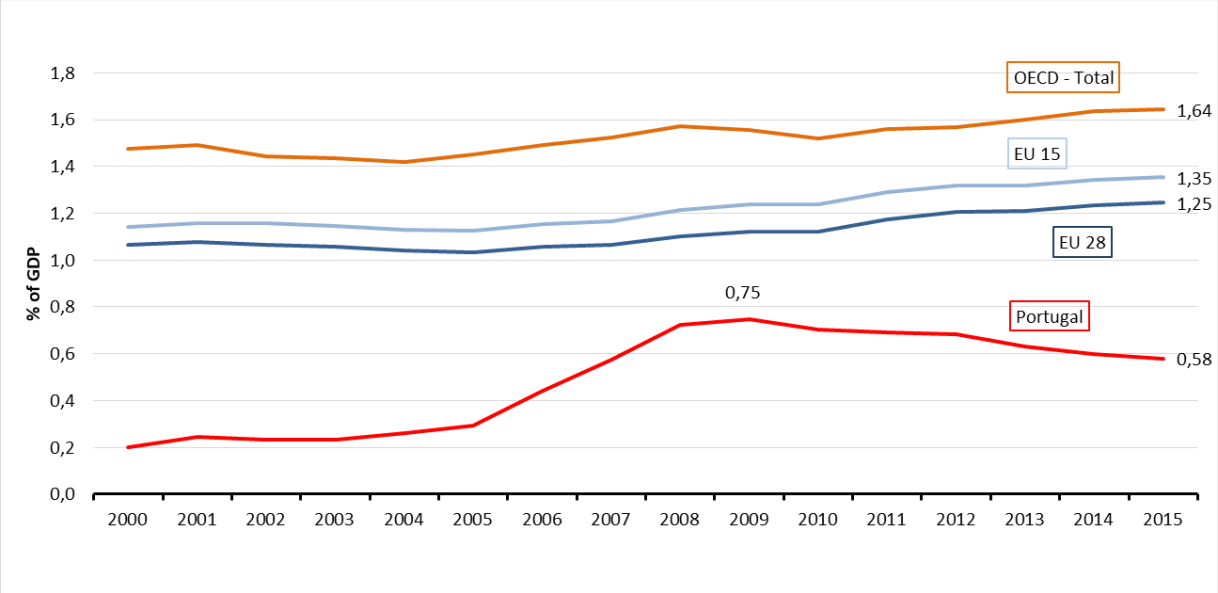
Figure 2.20
Gross expenditure in R&D (GERD), 2012 a 2016 (p)[2]



[2] [2] (a) In 2007 there was a process of enlargement and improvement of the administrative sources consulted to update the IPCTN business directory, which contributed to the increase in the number of R & D companies. (b) In 2008 there was a "Break in the series" resulting from the process of articulating the information of the IPCTN with the monitoring system of higher education teachers - REBIDES, which began to quantify in the Higher Education sector the R & D activity developed by teachers not reported by R & D centers. (c) the 2013 data for the distribution of R & D spending by sector reflect a series decline compared to previous years in the Higher Education and Nonprofit Private Institutions (IPSFL) sectors due to the sectoral re-allocation of several IPSFL to the Higher Education sector. This process was based on a thorough analysis of the criteria recommended in the Frascati Manual for the sector classification of R & D entities. Source: DGEEC.

- However, in the last five years, the investment in R&D decreased every year and it is nowadays around 1.28% of the GDP, being now lower than it was in 2008. During this period 2011-2015., Portugal followed the trend of expenditure reduction that was also seen in all the other countries in southern and eastern Europe. In 2016, the R&D started to grow again
- Portugal's gross domestic expenditure on R&D (GERD) was 2,347 million Euros in 2016 (p), i.e. 1.28% of GDP, being now lower than it was in 2008 This figure represents a decrease of more than 17% (in million Euros) compared to the peak that was reached in 2009. As a result, the Gross expenditure on R&D per capita was in 2015 of 221 euros, a mark that is 16% lower than it was in 2009 (262 euros per capita)
- The data shows the increasing role of higher education institutions as a driver of growth in Portugal's R&D. The tertiary education sector now accounts for approximately 46% of total Portuguese GERD and amounts to 1047 million Euros, up from 425 million Euros in 2005 (35% total Portuguese GERD at that time).

Figure 2.21
Business expenditure in R&D, Portugal vs EU & OECD



Source: OECD

- In 2016, the business sector accounted for 48% to the gross expenditure on R&D and the Higher Education sector accounted 45%. The share in terms of GDP was 0.61% in the business sector (1123 million Euros of total investment) and 0.57% in the Higher Education sector. The Government and Private Non Profit institutions accounted only 0.9% to the GDP.

2.2. FCT Funding

- The Portuguese Science and Technology Foundation (FCT) is the main R&D funding agency in Portugal. Its effective expenditure on R&D has decreased 21% since 2010 (after a period when it almost doubled from 2006 to 2010). The downfall of the FCT expenditure on R&D was made through the reduction on the funding of several programmes and actions, as follows:
    - Advanced training of human resources, including competitive programmes of PhD fellowships and postdoctoral grants. After an enlargement between 2006 and 2009, when it reached more than 2,550 new grants awarded per year (it was about 1500 in 2005), the number of fellowships and grants was sharply reduced, being in 2015 a total number of 1439, lower than a decade before.
    - Scientific employment, after the Programmes Ciência 2007 and 2008, that involved over 1,200 new contracts with an overall public expenditure of over 67 million Euros in 2010, was since then reduced to 38.8 millions
    - Institutional development, through a seed-funding programme for research units and Associate Laboratories throughout the country (in universities and related private, non-profit institutions), based on periodic evaluations, which involved over 96 million Euros in 2010 was reduced to 80 million in 2015.
    - Fostering competitive activities, through the systematic opening of national competitions for funding R&D projects in all scientific areas with an overall public expenditure of 69 million Euros in 2015, after have reached 85 million Euros in 2010.
    - After the downfall of the Government budget for R&D following the crisis, a upward trend is noticed since 2015 Budget. The 2018 Budget for FCT has a proposed increase of 10%, mainly to invest in the scientific employment programme.

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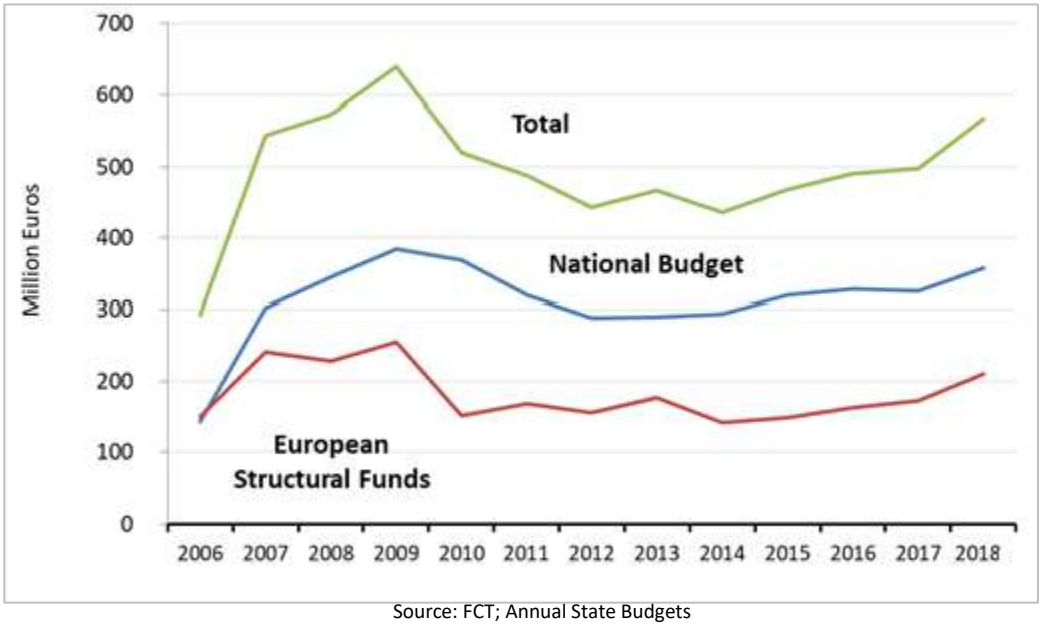
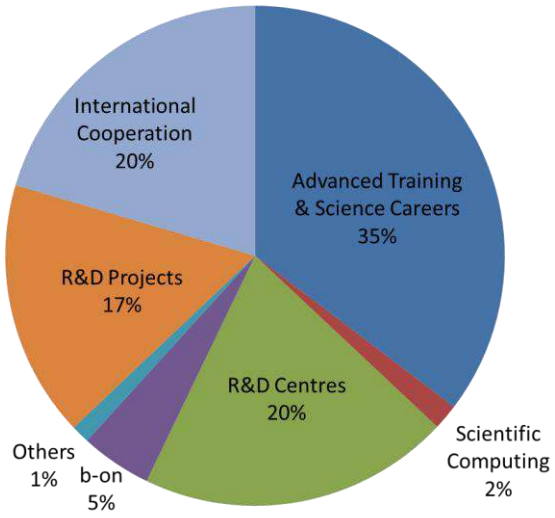
Figure 2.22
FCT Total Budget, 2016-2018



Source: FCT; Annual State Budgets

Figure 2.23
Shares of FCT Investment Expenditure, 2017



Source: FCT

- FCT regularly gives researchers the opportunity to submit applications for research projects. This is done both in competitions open to all scientific areas and through competitions aimed at targeted research in certain specific fields or themes, and the evaluation is carried out by panels of independent evaluators, involving national and foreign experts of recognized merit and suitability, established for each contest, by scientific area.

SAMPLE HIGHER EDUCATION INDICATORS FOR PORTUGAL

A - Enrollment	**2000/01**	**2005/06**	**2010/11**	**2014/15**	**2016/17**
Total students enrolled	387 703	368 571	403 445	358 450	361 943
Vacancies (new study places available)	84 130	83 931	89 813	72 520	73 295
Enrolled students for the first time- first year (Total, including mobility)	93 249	82 720	131 508	104 255	113 915
Students enrolled in tertiary education, aged 20, as a percentage of the corresponding age population	28,1%	30,0%	38,0%	39,0%	42,7%
Total enrollments in:					
Short-cycle tertiary (CET/TESP)	0	1 259	7 177	9 187	11 048
1st cycle	373 457	341 495	294 283	246 867	246 138
2nd cycle and other postgraduates programmes	10 865	17 312	83 692	82 931	84 998
3rd cycle (Doctoral programmes)	3 381	8 505	18 293	19 465	19 759
Number of foreigner students enrolled in HEI	12 717	17 077	21 824	33 552	42 564
Students enrolled for the first time after special competition "over 23 years of age"			10 242	4 826	4 909
Number of scholarships for low income students	59296	68964	67888	63628	71941
Total student loans (public system of mutual guarantee; accumulated)	n.a.	n.a.	11271	21764	21764
B - Graduates					
Total graduates	60 091	69 209	75 482	74 757	n.d.
Number of doctorates graduates in S&T	324	581	812	915	n.d.
Number of total doctorates graduates	585	1 094	1 608	2 351	n.d.
C - Attainment	**2001**	**2006**	**2011**	**2015**	**2016**
Tertiary educational attainment, age group 30-34 (%)	11,7%	18,3%	26,7%	31,9%	34,6%
Proportion of the tertiary graduated in active population (25-64 years old)	10,9%	15,2%	19,3%	25,7%	26,8%
Proportion of the tertiary graduated in resident population (25-64 years old)	9,2%	13,4%	17,2%	22,9%	23,8%
D - Faculty Staff	**2001/02**	**2009/10**	**2014/15**	**2016/17**	
Public Universities (Headcounts)	14 455	14 803	15 140	n.d.	
Public Universities (Full Time Equivalent)	n.a.	n.a.	11 734,69	n.d.	
Public Polytechnics (Headcounts)	9 841	10 289	9 353	n.d.	
Public Polytechnics (Full Time Equivalent)	n.a.	n.a.	7 281,88	n.d.	
Private Universities (Headcounts)	7 424	6 899	5 061	n.d.	
Private Universities (Full Time Equivalent)	n.a.	n.a.	3 460,38	n.d.	
Private Polytechnics (Headcounts)	4 700	5 017	2 792	n.d.	
Private Polytechnics (Full Time Equivalent)	n.a.	n.a.	1 718,36	n.d.	
Average age of academic staff at universities (Public and Private)	42	46	48	n.d.	
Average age of academic staff at Polytechnics (Public and Private)	40	42	45	n.d.	

Source: DGEEC

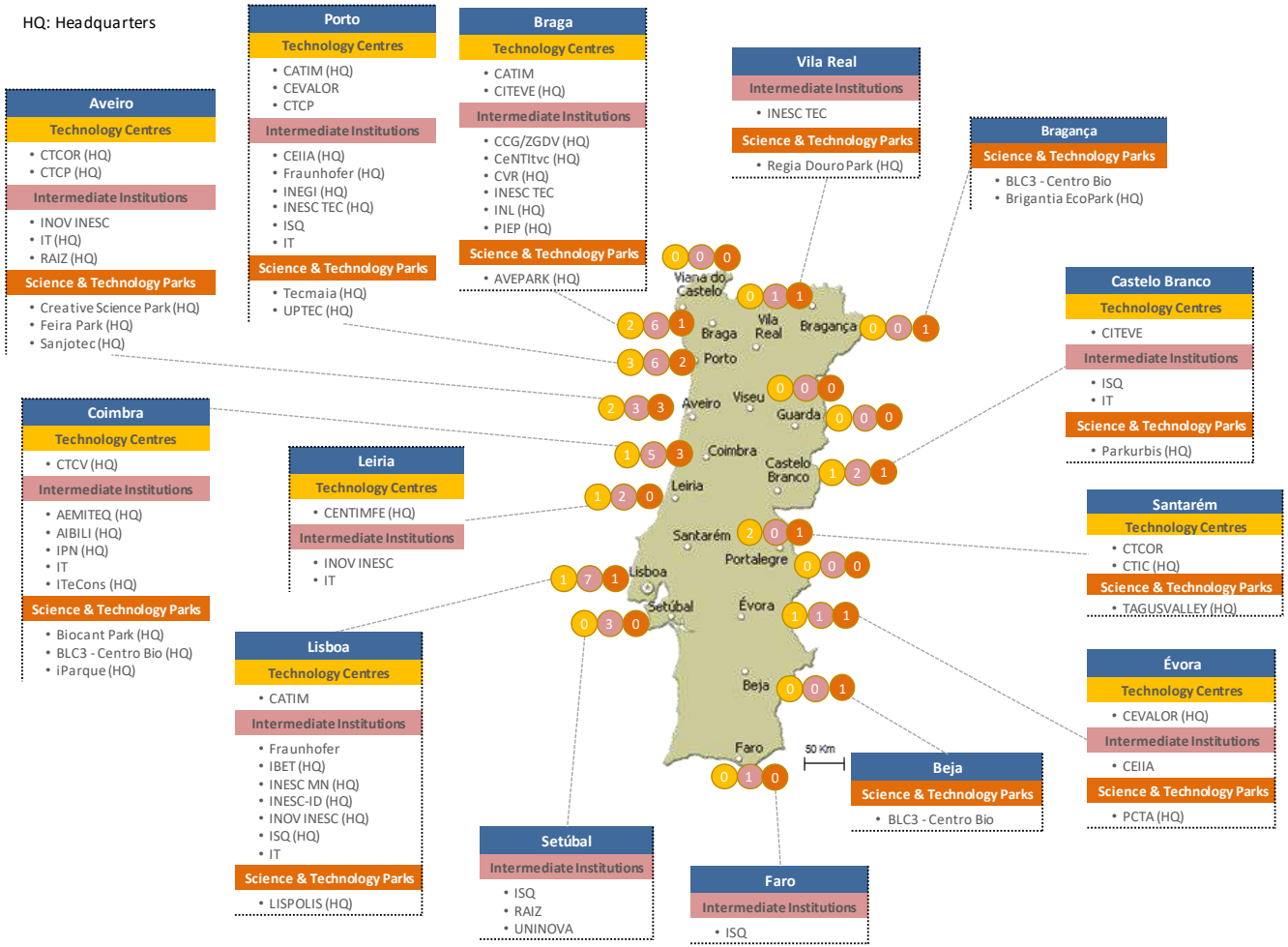
SAMPLE SCIENCE AND TECHNOLOGY INDICATORS FOR PORTUGAL[3]

A - GERD - GROSS DOMESTIC EXPENDITURE on R&D	Source	2001	2005	2010	2014	2015	2016
Gross Domestic Expenditure on R&D (GERD) as a percentage of GDP	a)	0,76%	0,76%	1,53%	1,29%	1,24%	1,27%
Gross Domestic Expenditure on R&D (GERD) (million €)	a)	1 038,4	1 201,1	2 757,6	2 232,2	2 234,4	2 347,7
Business enterprise expenditure on R&D (BERD) as a percentage of GDP	a)	0,24%	0,29%	0,70%	0,60%	0,58%	0,61%
Business enterprise expenditure on R&D (BERD) (million €)	a)	330	462	1,266,3	1 036	1 036,5	1 123,2
% of BERD on GERD	a)	32%	38%	46%	46%	46%	48%
GERD per researcher (thousand €)	a); e); f)	59	57	66	58	58	58
B - R&D PERSONNEL							
Total R&D personnel (FTE)	a)	22 969,6	25 727,8	47 615,9	46 877,6	47 992,2	50 912,0
Researchers (FTE)	a)	17 725,1	21 126,3	41 523,4	38 155,4	38 671,6	40 746,0
Researchers per thousand labour force	a)	3,3	3,8	7,6	7,3	7,4	7,9
Women researchers as a percentage of total researchers	a)	45%	45%	44%	44%	43%	
Researchers on HES and PNP (FTE)	a)	11 356,8	13 775,1	28 511,6	25 504,8	25 535,8	26 956,0
% of researchers (FTE) on HES and PNP	a)	64%	65%	69%	66%	66%	66%
Researchers on Business enterprise (FTE)	a)	2 721,9	4 013,6	10 571,8	11 203,2	11 784,6	12 490,0
% of researchers on Business enterprise	a)	15%	19%	25%	29%	30%	31%
R&D personnel on Business enterprise (FTE)	a)	3 874,9	6 133,4	14 036,3	17 347,8	18 283,1	19 650,0
Researchers on Government (FTE)	a)	3 646,4	3 337,6	2 440,0	1 447,5	1 351,2	1 301,0
Researchers on PNP (FTE)	a)	2 415,2	2 818,7	4 653,1	527,2	492,6	524,0
New Phd Grants awarded by FCT	b)	831	1 172	1 680	875	895	1 380
New Post-Doc Grants awarded by FCT	b)	358	637	618	486	549	426
Graduates at doctoral level	c)	585	998	1 414	2 503	2 351	2 344
C - SCIENTIFIC PUBLICATIONS		**2001**	**2005**	**2012**	**2013**	**2014**	**2015**
Number of publications indexed in Web of Science	d)	4 874	7 476	17 631	19 616	20 421	21 333
Number of publications indexed in Web of Science per m	d)	469	712	1 681	1 881	1 968	2 056

[3] Footnotes: * Figures for 2016 are provisional. Source: a) DGEEC (IPCTN); b) FCT; c) DGEEC (RAIDES); d) DGEEC (InCites); e) Eurostat; f) OCDE.Remark 1: National GDP figures were revised by the National Statistical Institute in late September 2014, after updating the base of the Portuguese National Accounts, which began to consider the base year of 2011, according to the methodological manual of the European System of National Accounts and Regional Policy (SEC 2010). This revision of GDP was made retrospectively for the whole series of years from 1995 onwards. Based on this review the data presented in relation to GDP differ from the data in publications prior to 2014. Remark 2 - Gross Domestic Product (B.1 * g) at current prices (Base 2011 - €). The totals presented may not correspond to the sum for reasons of automatic rounding.

MAP OF TECHNOLOGICAL INFRASTRUCTURES BY DISTRICT LOCATION (HEADQUARTERS AND OTHER FACILITIES)

HQ: Headquarters



Source: ANI