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TR@NSENER

European Regional Development Fund

AN OVERVIEW OF INNOVATION IN THE ENERGY SECTOR FOR THE SUDOE REGIONS

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INTRODUCTION

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Climate change is one of the biggest global challenges facing our society. This is a problem on an international scale and is one which must be dealt with decidedly and urgently, especially when considering the continual increase in the temperature of the Earth's surface due to the evolution of greenhouse gas (GHG) emissions of anthropogenic origin, as well as the social, economic and environmental impacts which are increasingly severe and irreversible.

Emissions of greenhouse gases (GHG) into the atmosphere have been increasing, mainly due to the use of fossil fuels. This makes the energy sector the main culprit for GHG emissions and is called upon to play a vital role in finding solutions for the huge challenge that humanity is currently facing.

The Paris Agreement of December 2015 signalled the end of more than two decades of global negotiations and paved way for a new approach that responds to the challenge of climate change through a transformation in how society produces and consumes. This agreement represents the first global binding agreement in which all countries, not only those in the industrialized world, have fully committed themselves to ensure that global warming is limited to less than 2°C compared to pre-industrial levels and if possible, even below 1.5°C. Limiting global warming to below 2°C requires a great effort, particularly in the energy sector, which currently generates around two thirds of global greenhouse gas emissions.

As a society, we must move towards a new energy paradigm that is low in terms of emissions while at the same time capable of guaranteeing a stable supply and economic competitiveness. Transforming our own energy model is no simple feat. There are great uncertainties around this process of change so it is necessary to define clear and resilient policies which are capable of responding to an ever-changing environment.

Completely decarbonizing the energy sector is a major challenge and requires technological development and the mobilization of significant amounts of investment at the very minimum. The idea of a world in which energy does not produce any emissions, the leading cause of climate change CO_2 in particular, still seems a very long way off. Currently, a zero-emission electric generation system seems unlikely. Even with the economically viable and scalable renewable solutions that are available to around two thirds of the world's energy supply, other aspects such as population growth and the increasing demand for energy could hinder the goal of decarbonizing energy if there is not urgent investment in Research and Development (R&D).

Therefore, energy transition cannot happen without a large innovative effort and the energy sector requires new and cleaner technologies that are already available. They simply need to be cheaper and more competitive in the markets. This requires an intelligent and sustainable system that allows for the creation of new innovative business models. And it is precisely in this area that this study, developed within the framework of the European innovation project Tr@nsener, seeks to offer its view on the state of the art of innovation.

The Tr@nsener project (European Cooperation Network on Energy Transition in Electricity), co-financed by the Interreg Sudoe Programme through the European Regional Development Fund (ERDF), was set up with the aim of promoting innovation abilities in the Sudoe geographical area (which covers the south of France, Spain and Portugal), guaranteeing an intelligent and sustainable growth and promoting research and technological development. The project had a duration of three years and involved various prominent institutions: University of Toulouse III – Paul Sabatier, the Foundation for Energy and Environmental Sustainability (FUNSEAM), the University of Lisbon, the National Centre for Scientific Research (CNRS), the CIRCE Foundation, the University of Beira Interior, Technical University of Madrid (UPM) and the Technological Corporation of Andalusia (CTA). During its duration, multiple and diverse actions have been taken in the interests of an improved system for innovation.

The current study is a result of this project and, with guidance of the leading experts in the field of innovation and, under the coordination of FUNSEAM, provides an insight on the state of the art solutions and recommendations for improving the current situation of R&D&I, a tool that will undoubtedly generate prosperity and economic growth in companies, sectors and countries.

Addressing the main problems in today's society, such as climate change, sustainable transport and renewable energies, does not only mean increasing sustainable financing and reorientation of capital flows and investments, it also has the essential requirement of achieving greater commitment to research and innovation in order to find economically viable and competitive low-carbon solutions. It is necessary for all efforts in R&D to be focused on finding transforming carbon-neutral solutions in areas such as electrification (renewable energies, smart grids and batteries), hydrogen and fuel cells, energy storage, transformation of energy-intensive industries, the circular economy and the bioeconomy to name but a few. There are undoubtedly many areas that require action which lead onto others of a social nature given the complex and multi-faceted nature of innovation. One of the determining elements of the adoption of innovative solutions is the human factor as it is necessary to take into consideration aspects such as the social acceptance of innovation or the effect of the question of gender in decision-making and, thus, we need to move beyond strictly technological issues.

It is with this in mind that this research has been designed and explores issues outside of an exhaustive and detailed compendium of technological areas of relevance in the search for innovative solutions to the challenge of transforming our energy sector. The hope for this research is that it contributes elements of reflection on the current situation and possible recommendations for improvement.

Starting with the analysis of the role of innovation and investment in R&D and its capacity to provide innovative breakthroughs which can respond to the challenge of energy transition and therefore guaranteeing access to affordable, safe and sustainable energy against a backdrop of increasing energy demand, María Luisa Castaño, provides her view of the Spanish Case, the challenges associated with the incorporation of these new technologies and especially to what extent this will affect the entire corporate structure and calls for new strategies in the definition and implementation of policies on innovation. Furthermore, Gilles Charier, offers a glimpse of the situation of innovation in France.

The second section attempts to highlight the relevance of energy innovation for the electricity sector in the case of the sudoe regions based on the main data on R&D and innovations in energy and its main actors, namely companies, which are the key agents in the innovation process. The contributions in the case of Spain of José García-Quevedo, in the case of Portugal of Rui Cartaxo, and in the case of France of Thierry Talbert and Cecilia Hinojosa, provide an overview of the situation of innovation in these respective geographical areas as they seek to identify the determining factors of business innovation and the effects that can be derived from the R&D and innovation strategies of energy companies.

Following this analysis of the current situation of innovation, the rest of the contributions explore issues, which are more specific but not less relevant, giving two perspectives on Innovation. From a technological perspective, the contribution made by José Francisco Sanz, focuses on electricity networks, given their role in energy transition and how innovation efforts should be focused on the integration of high levels of variable renewable energy in energy systems. Increasing the amount of electricity generation from renewable sources requires options that provide flexibility through the strengthening of the network, management on the demand side, energy storage and the combining of other sectors (greater electrification in the transport sector and heating and cooling systems). From an economic perspective, Manuel

Doblaré focuses on the analysis of the main requirements of any strong innovation system, identifying the strengths and weaknesses of the innovation systems in France, Portugal and Spain, as well as the comparison between them and with other countries with similar characteristics. The section concludes with some proposals for measures for improvement that would allow countries to overcome their main weaknesses. Finally, Aleix Pons and Javier Anatole place the emphasis on the role of the human factor and social acceptance of innovation. If one of the deciding elements of the existence, impulse or adoption of innovation relies on this human factor, it is necessary to bring together the social perception of innovation in general and the impact that society considers that innovation can have on the labour market in particular. To conclude this section, a transversal issue such as that of gender and how a greater presence of women in the scientific and technological worlds results in an improvement of scientific excellence and economic development is the focus of the analysis done by Mercedes Teruel.

We would not like to finish this introduction without having thanked all the authors for their valuable contributions, sharing their knowledge and providing their reflections on an issue as relevant as innovation. We would also like to thank all the researchers, academics, managers in the energy sector and anyone who participated in the reflection and analysis procedures and events that have occurred during the Tr@nsener project and who enriched the discussions and debates on important energy issues with their presence.

In the next two decades, a massive push for research, coordination and innovation will be needed in order for low or zero carbon emission solutions become economically viable and to promote new solutions that are not yet mature enough or unknown to the market. It is with a position of modesty that we hope that this research can make a fair contribution to a better understanding of the current situation as well as any deciding factors that condition the success of any system of innovation.

Joan Batalla
José García-Quevedo

ABSTRACTS

INNOVATION AND ENERGY TRANSITION

THE SPANISH AND FRENCH CASES

The decarbonization of the economy is considered to be a good opportunity for economic development and job creation through the appropriate orientation of R&D&I policies, which facilitate adaptation to technological changes. It is also an opportunity to promote a modern energy sector, which is capable of attracting investment in R&D and which promotes a robust industrial sector within a context of global energy transition. Two outstanding institutions such as the Centre for Energy, Environment and Technology (CIEMAT) and the DERBI Competitiveness Cluster offer their vision of the role that R&D&I and technology can play in the transformation of sectors such as energy, construction, transport and industry and the business opportunities from new energy innovations.

CURRENT SITUATION OF INNOVATION IN THE ELECTRICITY SECTOR

OVERVIEW OF THE SITUATION IN SPAIN

There is a broad consensus on considering innovation to be a fundamental factor in facing challenges related with efficiency, environmental impact, and the security of supply of energy. This study presents an overview of R&D and innovation in energy in Spain. First, the principal characteristics and recent developments in innovation in the utilities and the factors that explain their investment decisions in different innovative activities are presented. Second, information about the investment in R&D on the part of manufacturing industries directed towards energy is presented and the factors explaining this investment are discussed.

This study finishes with some brief reflections in which the need to increase expenditure on R&D and innovation in energy is underlined, as well as the importance of collaboration between different public and private agents and the significant role which public policy should play in encouraging innovation in energy.

OVERVIEW OF THE SITUATION IN PORTUGAL

Portugal had a state monopoly for the transport, distribution and commercialization of electricity, as well as the various hydroelectrical and/or coal centrals, until 2000. Since then, there was a separation between the incumbent operator, EDP, and the newly created transmission system operator, REN, which has the monopoly of the operation of electricity and natural gas networks. Both were 100% privatized. EDP's main competitors are large Spanish operators.

Portugal has seen a strong emergence of renewable energies, mainly hydric and wind, with the incumbent EDP playing a major role, but is lagging in solar.

Portugal has a very strong position as regards sustainable mobility, with electric cars penetration being the 4th highest in the EU. The Government has a reliable plan for the horizon 2021-2030 for the decarbonization of the economy and for the consolidation of renewable energies.

OVERVIEW OF THE SITUATION IN FRANCE

The French public strategy was established in order to overcome the new technological, environmental and societal challenges at a local, national and European level.

The first section of the chapter provides a brief description of the R&D and Innovation System in France, covering the main support systems and public investment in the energy sector. Then, the chapter briefly reviews the main innovation strategies developed by the enterprises concerning the development of new technologies in the energy sector. Finally, in the last paragraph, the perspectives of future research and development in correlation with the evolution of the electricity price chosen by the French Commission Regulation are presented.

TWO PERSPECTIVES ON INNOVATION

INNOVATION FROM A TECHNOLOGICAL PERSPECTIVE

The current electrical power system (EPS) has been designed so that the flow of energy is unidirectional: from the large generation plants to the consumers. This system has important limitations that, among others, limit the deployment of renewable energy. Renewable energy, which can be used almost anywhere, gives rise to the concept of Distributed Generation (DG), which however cannot be used without a major transformation of the current EPS towards what is called the smart grid. For smart grid to be possible, it is necessary to produce a series of technological developments, ranging from new materials, through new technologies, software development and communications, and the deployment of microgrids. In this chapter, starting from the justification of the need to change the current EPS, the concepts of DG and smart grid are presented, and a brief review of some of the necessary technological developments is made.

INNOVATION IN THE NEW ECONOMY. REQUIREMENTS FOR A HEALTHY INNOVATION SYSTEM

This chapter describes the main characteristics of the new economy in which we are immersed characterized by the exponential growth of the technological advances and the increasing value of knowledge and innovation. It also discusses the main dimensions and indicators of an innovation system, and revise the role of its main actors: administration, companies, research and innovation centres and the whole society itself. Next, it addresses the main requirements for having a healthy innovation system and identify the main weaknesses and strengths of the ones in France, Portugal and Spain. Finally, some proposals are made for their improvement.

INNOVATION IN TODAY'S SOCIETY

SOCIAL ACCEPTANCE OF INNOVATION

This chapter synthesizes the main conclusions of two complementary approaches that Cotec has carried out on the social perception in Spanish society in general and the impact that this society considers that technological change will have on the labour market in particular. The first approach consisted of the largest demoscopic survey conducted to date in Spain regarding this issue. The second was a pioneering experiment that followed the methodology of experimental and behavioural economics. Spanish society has an overall positive view of the phenomenon of innovation, although people are increasingly aware of the challenges, risks and opportunities that technological change poses.

THE ROLE OF INNOVATION FROM A GENDER PERSPECTIVE

The influence of gender diversity on innovation is an issue of interest for policymakers and firms. Understanding the effects of gender diversity in terms of innovation is important to assess the impact of these changes. Gender differences at individual and team level influence group decision-making and subsequent innovation. The mechanisms, though, are the investment decisions, internal management and corporate governance. At firm level, the evidence shows that gender diverse teams may have negative impacts, but also positive. At territorial level, there is evidence that more innovative countries are more gender equal. The success of policies and actions at firm level depend of a large number of decisions such as the hiring process, the internal promotion, internal training, and innovation process, among others.

INNOVATION AND ENERGY TRANSITION

THE SPANISH CASE

María Luisa Castaño (CIEMAT - Centre for Energy, Environment and Technologic Research)

BACKGROUND

The development of modern society and its industrialization that has been dependant on using huge amounts of fossil fuels have together caused an increased presence of greenhouse gasses (GHGs) in the Earth's atmosphere. The main consequence of this is an increase in the planet's temperature. In order to break the existing link between economic development, energy consumption and GHG emissions, it is necessary to change the energy paradigm, reorienting it towards a model of production and use of low-carbon energy, which would slow down and reverse global warming and also guarantee economic growth which is sustainable in the long term. The existence of two historic agreements, the 2030 Agenda for Sustainable Development and the Paris Agreement on Climate Change, establishes the basis for this change that is beginning to form a part of the political and social agenda of the majority of the world's countries.

Following the aforementioned Paris Agreement, the European Commission developed the legislative package 'Clean Energy for all Europeans', which focuses on meeting the European climate goals by 2030 of lowering the levels of harmful emissions to 40% below 1990 levels and increasing the use of renewable energies to more than 32% by 2030 as well as improving energy efficiency by 30%. In addition, it states the Member States' obligation to draw up National Energy and Climate Plans in the lead up to 2030 and incorporate them into their national legislation.

Spain, being involved in this process, has recently developed its Strategic Energy and Climate Framework proposal, which includes the Law for Energy Transition and Climate Change, the National Energy and Climate Plan (NECP) and the Energy Poverty Strategy. In the case of the NECP, the ambitious objectives include a reduction of 21% greenhouse gas emissions on 1990 levels, 42% of the country's total energy use to be renewable by 2030 (which, in the case of electricity generation, this increases to 74%), and an improvement of 39.6% in energy efficiency.

To achieve these objectives, five areas in need are identified: Decarbonization, Energy Security, Internal Energy Market, Energy Efficiency and finally Research, Innovation and Competitiveness. The incorporation of the final area illustrates the strong commitment to research and innovation in order to overcome technical challenges, not only for the use of renewable energies but also for radical energy transformation.

Decarbonization of the economy is considered to be the main opportunity for economic development and job creation, through the appropriate application of R&D&I policies which facilitate adaptation to technological changes. It is also an opportunity to promote a modern energy sector, capable of attracting investment in R&D and which promotes a robust industrial sector against a backdrop of global energy transition.

R&D AND TECHNOLOGY

In recent years, the clean energy sector has been characterized by its huge capacity for dynamism and thanks to research and innovation, it has seen an unprecedented drop in costs, with more power installed per year than ever before and the birth of innovative businesses that are changing the way that energy is produced and used.

The transition of energy towards a decarbonised economy has been set into swift motion in the electricity sector, in which it is easy to see that the greatest opportunities for research and innovation will be focuses of the development of new energy technologies, increasing self-consumption and the development of storage systems in the broadest sense possible. The ambitious objective of renewable energy use in Spain (42% of the total energy) means that storage has a strategic value in the development of energy transition and planning of future energy systems. Storage systems mean that a balance between generation and consumption can be ensured, transmission and transport networks are more efficiently managed, demand is more effectively controlled and intelligent networks are enhanced. Looking to the future, hydrogen is becoming increasingly advanced as an energy and storage vector. The opportunity to produce hydrogen competitively using surplus renewable energies or using reformed bioproducts from processed waste provides an opportunity that has not been considered thus far.

On the other hand, an area that still needs to be explored is the decarbonization of sectors such as construction, transport and industry, where attempts towards transition have barely begun. In these areas, energy needs for heating and cooling, which represent approximately half of global energy use, still come from fossil fuels. There is therefore an obvious opportunity for using renewable energy sources in the fields of heat and cold production (by using biomass, solar energy or geothermal energy) in order to meet the growing needs for energy in the urban environment.

Similarly, industrial energy transformation is another area where research and innovation are a hot topic, given that there are industrial processes with high demands for heat, steam and industrial cold – needs which will be difficult to meet through electrical generation. It is clear that it will be necessary to further our knowledge in order to develop, apply and validate solutions that allow the industry to adapt to the challenges of a decarbonized society.

In the case of the transport sector, albeit steadily moving towards electrification, it is still based on the use of petroleum derivatives, with only 2.8% of the demand being met with biofuels and 1.3% with electricity. It is true that electric vehicles are destined to play a decisive role in mobility, especially in the urban environment. However, a very attractive alternative is the use of advanced biofuels, and in particular the development of those obtained in a sustainable manner from renewable raw materials (biomethane or hydrogen-based technologies).

Evidently, the transversality of energy efficiency, which affects industry, transport or construction, presents excellent opportunities for all technology solutions, often through a combination of various clean energies.

Finally, the obligation imposed by the European Union on waste management has meant that making use of the energy in waste, be it urban, rural, agri-food farming or industrial, has turned into an unprecedented, unique challenge. The possibility of obtaining renewable gas as a sub-product of waste treatment, which can be used directly to cover in-situ energy needs, be incorporated into the conventional gas network or even stored and transported for unrelated uses throughout the network, provides a wide range of opportunities for businesses, markets, jobs and technologies still waiting to be developed.

To conclude, research and innovation are crucial when facing the technical challenges in energy transition, especially to enhance the technological areas where there is already competition or a leading position, or one with a greater potential for socioeconomical benefit due to local implementation or contribution to the flexibility and optimization of the energy system as a whole.

THE SPANISH SYSTEM OF ENERGY RESEARCH AND INNOVATION

In Spain, the framework for research and innovation is defined in the Spanish Strategy for Science, Technology and Innovation (EECTI) and in the State Plan for Scientific and Technical Research and Innovation. In the future EECTI for the period 2021-2027, the possibility of a Strategic Action on Energy and Climate Change will be considered; its aims being to cover the implementation of science and technology. This Strategic Action will seek to promote research, innovation and competitiveness for energy transition, push for the full decarbonisation of the economy and the implementation of a sustainable development model. Entities involved in the development of this probable Strategic Action include the Public Research Organisms such as the Centre for Energy, Environment and Technological Research (CIEMAT), which, in addition to being the centre of reference research in energy, may play a relevant role as a nucleus for the creation of networks and the opening of a dialogue between interested parties, both public and private.

One of these networks is the Alliance for Energy Research and Innovation (ALINNE), a public-private collaborative initiative which is chaired by CIEMAT and works towards the coordination of different research, innovation and competitiveness agents in the energy area. This resource, operating in line with the state's scientific and technological policy, is inspired by the Energy Technology Platforms (team work forums led by the industry), which integrate all aspects of the Science-Technology-Innovation system of a particular energy sector in order to define the short-, medium- and long-term vision of the sector and establish a strategy to achieve it. The main result of ALINNE is the paper 'Analysis of the development potential of energy technologies in Spain' which has made it possible to evaluate, select and prioritize 13 energy technologies, and constitutes a unique exercise which will prove useful for the development of research and innovation strategies in energy.

Additionally, in collaboration with the Energy Technology Platforms, ALINNE has defined a series of 'Priority Technological Initiatives' (ITPs) to ensure greater success in making products and services arrive to the market, thus making both economic and human resources used in the development of technology profitable. These include initiatives in the Industrial Sector, Construction, Electric Generation as well as transport and Energy Vectors.
Finally, at a regional level, in accordance with the Agreement of Association between Spain and the European Union, the national framework of intelligent specialization (RIS3) is defined. Within this, the Autonomous Communities specify this intelligent specialization based on their own research and innovation strategies. It is within this framework that the S3-Energy Platform, created by the European Commission, is particularly important in order to align research and innovation for energy and climate objectives, bring regions together and to avoid possible fragmentation.

Multidimensional strategies for science, technology and innovation, which are linked to the objectives of Energy Transition, must contribute to the process of energy transition and to the effective coordination of all efforts made by affected parties. In the same way that decarbonization is a challenge affecting many sections, R&D entities can strategically position themselves somewhere along the chain of innovation, favouring the potential transversal benefit. In this context, it is essential to strengthen the mechanism that rely on the existing infrastructure of science and research, in order to identify opportunities for the future and develop new capabilities. The creation of an attractive environment to develop new initiatives in research and innovation should consider a greater degree of competitiveness based on entrepreneurial initiative and collaboration that has the support of the public administration and also promotes private investment in innovation.

THE FRENCH CASE

Gilles Charier (Derbi Competitiveness Cluster)

France has a world-renowned energy research community. It has a major demonstration facility and public-private partnerships for new energy technologies. Support for research and innovation is one of the major axes of the energy transition to support the corresponding sectors towards maturity and competitiveness.

Public spending on energy R&D amounted to €944 million in 2016, of which €408 million was on new energy technologies.

Focusing on the smart grid sector, since 2008, the development of Smart Grids in France has led to the emergence of 118 demonstration projects for a total investment of more than 500 million euros. As such, it ranks first among the countries of the European Union for investment, followed by the United Kingdom with 497 million euros and Germany with 363 million euros.

Since 2011, a team from the European Commission's Joint Research Centre (JRC) has been doing inventories, documenting and analyzing all demonstration projects and deployments of Smart Grids in Europe. The resulting database includes 459 projects totaling EUR 3.15 billion, of which 238 completed projects (EUR 1.15 billion) and 221 ongoing projects (EUR 2 billion). These projects involved 1,670 organizations in Europe, with an average of six partners per project, distributed throughout Europe as detailed below.

France and Spain account for 27% of investments and 16% of projects. The Sudoe area (France Southwest, Spain, and Portugal) is particularly well-represented with projects such as Smart Occitania, SoGrid or Digisol.

It is against this backdrop that the Tr@nsener project was formed. It aims to boost relations and interconnection between scientific, technological and business support networks in the development of their innovations and be at the service of the power networks.

CURRENT SITUATION OF INNOVATION IN THE ELECTRICITY SECTOR

OVERVIEW OF THE SITUATION IN SPAIN

José García-Quevedo (Universitat de Barcelona)

INTRODUCTION

The European Union emphasises the fact that innovation is a fundamental element in managing an efficient transformation of the energy system as proposed in the Energy Union Strategy and to comply with the Paris Agreement (European Commission, 2016; 2018). Technological advances in energy can have considerable economic and environmental benefits and innovation in the energy sector is key in facing challenges related with efficiency, environmental impact and the security of supply. The energy transition requires innovations in production, transport, distribution and in the services offered to consumers (European Commission, 2016). Innovation in energy affects a large part of the activities of the sector such as the generation of renewable energy, the storage of energy, smart networks or the provision of new services.

In the Spanish Strategy for Science, Technology and Innovation 2013-2020 there appear two important challenges which are "Secure, efficient and clean energy" and "Action on climate change and efficiency in the use of resources and prime materials". These challenges are also present in the objectives proposed by the European Commission in climate and energy matters for 2030. In both cases the need is underlined to increase efforts in investments in innovation to face the challenges of energy transition and climate change.

The energy sector in Spain is of a strategic nature and has considerable weight in production as a whole. However, the amount of effort in innovation, although important in absolute terms, is insufficient considering the size and importance of the sector (Molero, 2002). Economics for Energy (2013) also points out that innovation in energy in Spain could encourage the creation of new businesses and activities and the generation of added value and employment but that, nevertheless, there is not enough innovation in energy technology.

After this introduction, this document is organised in the following way. First the main characteristics and data about R&D and innovation in utilities in Spain are presented. In the next section, given the important role played by the suppliers of components and equipment in innovation in the energy sector, data for R&D in energy for the manufacturing sectors is presented and the conclusions of existing studies about their determinants are provided. Finally, the main trends of innovation in energy are examined together with some brief reflections on public policies to encourage innovation in energy.

R&D AND INNOVATION IN UTILITIES IN SPAIN

The energy industry shows, in spite of its importance in the economy, a low level of expenditure on R&D in comparison to other sectors, not only in Spain but also in other countries. With the beginning of the liberalisation process in the 1990s a fall in investment in R&D by utilities was also seen in the majority of European countries, although a slight recovery has taken place in recent years. (Jamasb and Pollitt, 2015). An analysis of the business investment in R&D of utilities should take the existing situation of competition into account. Competition imposes a competitive strategy focused on the efficiency of processes in order to reduce costs and increase margins and in a differentiation in contracts, as electricity is – as is gas – a homogenous product.

Analyses of R&D and innovation in energy are confronted with the limitations of information and the availability of data bases (GEA, 2012). The absence of a unique indicator to describe innovation means that it is necessary to use various input indicators, such as investment in R&D, and regarding the results. In addition, there are difficulties in delimiting the sector. A substantial part of innovations in energy do not occur, as has been pointed out previously, in the energy sector – generation, transport, distribution and consumption of energy – but take place in other manufacturing sectors such as machinery and electronic equipment (Molero, 2012; García-Quevedo, 2018).

The main sources of information in Spain for the analysis of R&D and innovation in firms are the Statistics on R&D Activities and the Survey on Innovation in Firms compiled annually by the Spanish National Statistics Institute (INE) with internationally equivalent criteria in accordance with the Frascati and Oslo Manuals of the OECD (OECD 2002; 2005). For the analysis of innovation in Spain there is also the Spanish Technological Innovation Panel (PITEC). The PITEC is a data base created by the INE and the Spanish Foundation for Science and Technology in consultation with a group of academic experts and allows the monitoring of technological innovation activities in Spanish firms.

The main data for the petroleum industries (NACE 19, Manufacture of coke and refined petroleum products) and activities in energy and water (NACE 35, Electricity, gas, steam and air conditioning supply, and NACE 36, Water collection, treatment and supply), that the statistics of the INE present combined, are shown with the data for all the firms in Table 1. In addition, in Figure 1, data facilitated by the INE covering activities in energy exclusively (NACE 36) are provided.

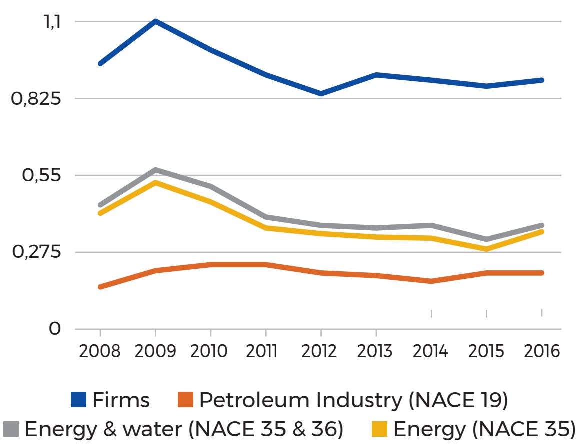
TABLE 1. R&D AND INNOVATION IN ENERGY. FIRM SECTORS. 2016.	Petroleum industries	Energy and water	Total firms
Firms that perform R&D	5	86	10,325
Internal expenditure on R&D (thousands of euros)	61,464	131,206	7,125,973
Employees in R&D (FTE)	414.4	1,237.1	90,129
Purchase of R&D services (thousands of euros)	20,348	85,627	1,852,538
Innovative firms	6	134	18,475
Percentage of innovative firms	71.43	21.55	12.75
Innovation intensity	0.20	0.37	0.89

Source: Spanish Institute of Statistics (INE) and own elaboration

These sectors contain a small number of generally large firms, a large part of which are innovative. These firms carry out a substantial part of their technological activities by acquiring R&D services. In both sectors the proportion of external purchases of R&D in relation to internal expenditure is notably greater than in the economy as a whole.

The two sectors also have a level of innovation intensity (expenditure on innovation over turnover) below the average for firms. This is, as was pointed out previously, also a common feature of these sectors in other European countries (GEA, 2012). This intensity has remained stable in petroleum industries, even in the crisis period, while in the energy and water sectors it has fallen, as it has amongst firms as a whole. In these two activities, as shown in Figure 1, the behaviour of energy activities has a determining influence. Expenditure on innovation in the energy sector represents more than 85% of the total on innovation in the activities covered by energy and water together.

FIGURE 1. INNOVATION INTENSITY
(Expenditure on innovation as a percentage of sales)

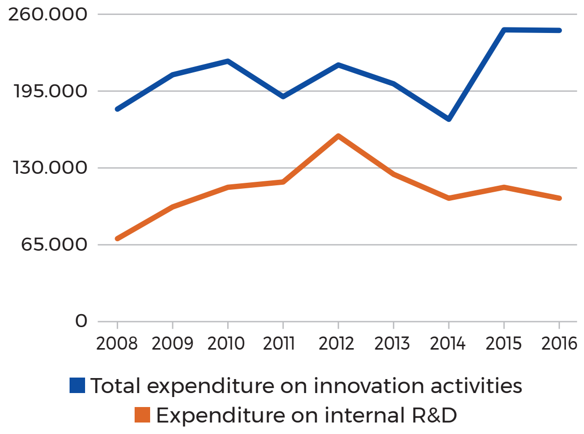


Source: Spanish Institute of Statistics (INE) and own elaboration

After the innovation intensity presented in Figure 1, Figure 2 shows the evolution of total expenditure on R&D and innovation in the period 2008-2016 for energy industries (NACE 35) exclusively, from information provided directly by the INE. The evolution of the total expenditure on innovation of energy utilities shows the effects of the crisis, with considerable falls in 2011 and 2014, but also the very noticeable recovery that took place in 2015 and 2016

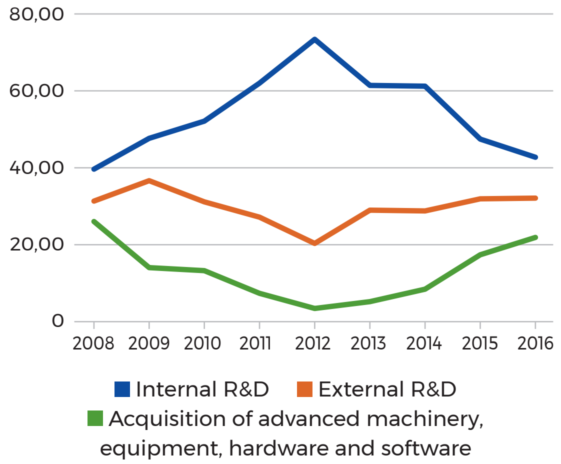
Investment in internal R&D is the main input for increasing the stock of knowledge and when innovating, but innovation has many sources other than internal R&D. Firms can also purchase external R&D or even acquire machin-

FIGURE 2. TOTAL EXPENDITURE ON R&D AND INNOVATION ACTIVITIES
of "Electricity, gas, steam and air conditioning supply" (NACE 35). Thousands of euros.



Source: Spanish Institute of Statistics (INE) and own elaboration

FIGURE 3. DISTRIBUTION OF THE EXPENDITURE ON INNOVATIVE ACTIVITIES
(internal R&D, external R&D and acquisition of advanced machinery, equipment, hardware and software) of "Electricity, gas, steam and air conditioning supply" (NACE 35). In %.



Source: Spanish Institute of Statistics (INE) and own elaboration

ery in order to innovate and improve their technology level. The choice of R&D strategy has received considerable attention in the economics of innovation literature. In Figure 3 a breakdown is given of expenditure on innovation in energy activities (NACE 35) into its three main components: internal R&D, external R&D, and the acquisition of machinery, equipment and hardware or advanced software.

This breakdown shows two important traits. First the evolution of total expenditure on innovation is closely related to developments in the acquisition of advanced machinery, which fell notably in the crisis period, specifically between 2011 and 2014. On the other hand, the amount of expenditure in absolute terms on R&D was more stable, as Figure 2 shows. Second, the weight of acquisition of R&D – external R&D – stands out for its stability throughout this period taking a share notably above that of firms as a whole in Spain (15.2% in 2016).

Costa-Campi et al. (2019) analyse the characteristics of energy firms that explain their investment decisions in these three main types of source of innovation – internal R&D, external R&D, or the acquisition of machinery or advanced equipment –. First it is examined whether variables such as size, age of the firm, reception of public funding or the participation of foreign capital influence decisions to invest in R&D internally or externally, or to acquire advanced machinery or equipment. In addition, the possible persistence of innovative activities over time is taken into consideration in the analysis.

Second, firms dedicate resources to innovation for different reasons. This study distinguishes between four possible motives: innovation related to products – e.g. improve the quality of service, the provision of new services or entering new markets –; innovation related to processes – increase the flexibility or the production capacity –; innovation with the object of reducing environmental impact and, finally, innovation oriented towards complying with environmental or health and safety regulations.

The results show that investment in innovation is highly persistent over time. This is so with internal R&D as well as the acquisition of external services. As regards the objectives of innovation, the results show significant differences. The internal and external R&D of energy firms is mainly related with the reduction of environmental impact and complying with regulations while the introduction of process innovations is the main factor driving the acquisition of machinery and advanced equipment. Finally, the results show that there is a notable complementarity between carrying out internal R&D and acquiring external R&D services, which demonstrates the importance that combining the use of internal resources with the use of external sources of R&D has for business innovation and increasing knowledge stocks.

R&D INNOVATION IN ENERGY IN MANUFACTURING SECTORS

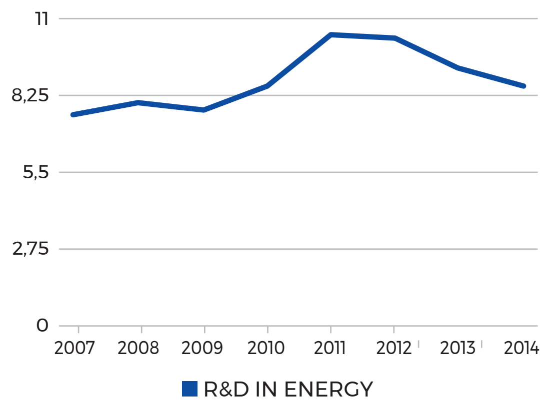
Energy investment in non-energy sectors is a very important factor to take into consideration when determining technological advances in energy. Wiesenthal et al. (2012) stress the important contribution made to it by the sector's component and equipment suppliers. Similarly, Sanyal and Cohen (2009) point out that the producers of energy equipment have conducted most of the R&D and generated most of the innovations made in the energy sector.

Therefore, in the analysis of the activity of firms in R&D and innovation in energy it is important to take possible expenditure on R&D in energy in other industrial sectors apart from the utilities into consideration, particularly given the powerful knock-on effects that the sector has on other economic and innovative sectors.

This information is not usually available in surveys and statistics of R&D and innovation. Data for R&D is normally gathered for economic sectors and not for technologies. In Spain however, since 2008 firms have been asked in the Innovation in Companies Survey – the Spanish version of the Community Innovation Survey – to divide their internal investments in R&D according to the socio-economic objective (SEO) they have (García-Quevedo, 2018). This division is based on criteria defined by the OECD in the Frascati Manual (OECD, 2002). One of these objectives is the production, distribution and rational utilisation of energy. Specifically, SEO 5 covers: "research into the production, storage, transportation, distribution and rational use of all forms of energy". It also includes research on processes designed to increase the efficiency of energy production and distribution, and the study of energy conservation. It does not include research relating to prospecting (SEO 1) nor research into vehicle and engine propulsion (SEO 7). Nor does this SEO include research into the control and care of the environment, an area that corresponds to SEO 3.

The data for all manufacturing sectors (Figure 4) shows the importance of the volume of R&D expenditure dedicated to energy. In the period 2008-2014 between 8% and 10% of all business expenditure on R&D had energy as its objective.

FIGURE 4. EXPENDITURE ON INTERNAL R&D IN ENERGY
(as a percentage of total expenditure on internal R&D).



Source: Spanish Institute of Statistics (INE) and own elaboration

The information by manufacturing sectors shows that all of them dedicate part of their R&D expenditure to the objective of energy, although there are significant differences. The production of electrical material and equipment, other machinery and equipment, and information technology, electronic and optical products are particularly important.

Together with the important role played by suppliers in developing energy R&D, other factors may also drive R&D investments in non-energy firms. Manufacturing firms may invest in R&D to improve their energy efficiency or to achieve energy self-supply. The regulatory measures that enforce improvements in energy efficiency and the reduction of emissions, the security of supply or anticipate complying with energy or environmental regulations can explain R&D decisions in energy beyond the energy sector and its suppliers.

In Costa-Campi and García-Quevedo (2019) the motives for investment in R&D in energy are examined in manu-

TABLE 2. BUSINESS R&D INVESTMENT WITH AN ENERGY OBJECTIVE IN SPAIN
(in percentage of the total internal R&D of each sector 2008–2014).

Food, beverages and tobacco products (10, 11, 12)	6.46 %
Textiles, wearing apparel, leather and related products (13, 14, 15)	6.80 %
Wood, paper and printing (16, 17, 18)	8.07 %
Chemicals and chemicals products (20)	8.35 %
Pharmaceutical products and preparations (21)	3.22 %
Rubber and plastic products (22)	5.60 %
Other non-metallic mineral products (23)	5.96 %
Basic metals (24)	7.82 %
Fabricated metal products, except machinery and equipment (25)	6.54 %
Computer, electronic and optical products (26)	11.67 %
Electrical equipment (27)	21.88 %
Machinery and equipment n.e.c (28)	14.51 %
Motor vehicles, trailers and semi-trailers (29)	2.95 %
Other transport material (30)	1.46 %
Furniture (31)	4.18 %
Other manufacturing activity (32)	1.23 %
TOTAL INDUSTRY	9.54 %

Note: Between brackets, codes (divisions) of the NACE Rev. 2 – Statistical Classification of Economic Activities in the European Community.

Source: own elaboration based on data provided by the Spanish Institute of Statistics (INE).

facturing sectors. The results show the importance that the suppliers of energy firms have in explaining R&D in energy. Instead, innovation in energy efficiency zis solved preferably by buying machinery and not with investments in R&D. The results of the analysis applied also show the importance of public support and subsidies for R&D to encourage entrepreneurial effort in energy R&D.

TRENDS IN ENERGY INNOVATION AND PUBLIC POLICY

In the analysis of innovation in energy it is necessary to take the fact into account that various agents, both public and private, intervene. The most important are the utilities themselves and the technology suppliers. In addition, public policy may play a very important role in technological advances in the sector.

Existing analyses for Spain (Molero, 2012; García-Quevedo, 2018) point out that, in the same way as in other countries, investment in R&D by utilities is still too small to confront the challenges in the sector and that the necessary increase in effort in energy R&D not only affects the firms in the sector but all the productive processes involved in the value chain (European Commission, 2018).

Technological advances in the sector could be favoured by the collaboration of energy firms with other public or private organisations. The literature on innovation contains the concept "open innovation", as a way for firms to innovate in a collaborative way (Chesbrough, 2006). Open innovation allows the costs and risks of the innovation process to be shared between various firms and considers that the knowledge inside a firm may not be enough to develop certain innovations. It is a concept particularly applicable to the energy sector as the innovation projects generally require large quantities of capital, are faced with numerous uncertainties and require ever more specialised knowledge.

To achieve the technological advances that the sector needs it seems also desirable to reinforce public intervention with the purpose of encouraging R&D in energy. In particular, public support is fundamental for those projects that require long periods of research and contribute disruptive innovations directly focused on mitigating climate change (European Commission, 2018). These are projects situated in the field of scientific applications that are not yet marketable and therefore require public policy for their implementation, the encouragement of collaborative R&D among the energy firms and firms in other sectors and public-private cooperation (Henderson and Newell, 2010; Newell, 2010, Jamasb and Pollit, 2015).

To sum up, as the recent proposals of the European Commission point out on the climate and energy issue, advances in innovation in energy are fundamental in reaching the objectives set for 2030. This requires reinforcing energy policy, giving a fundamental role to support for R&D and innovation (European Commission, 2015; 2018).

REFERENCES:

Chesbrough, H., (2006). Open innovation: a new paradigm for understanding industrial innovation In: Chesbrough, H., W. Vanhaverbeke, W., West, J. (Eds.), Open Innovation: Researching a New Paradigm. Oxford University Press, Oxford, pp. 1–12.

Costa-Campi, M.T., Duch-Brown, García-Quevedo, J. (2019). Innovation strategies of energy firms. Corporate Social Responsibility and Environmental Management, 2019. https://doi.org/10.1002/csr.1787 (in press).

Costa-Campi, M.T., García-Quevedo, J. (2019). Why do manufacturing industries invest in energy R&D? Economics of Energy & Environmental Policy (forthcoming).

Economics for Energy, (2013). Innovación en energía en España. Análisis y recomendaciones. Informe 2012. Economics for Energy, Vigo, Spain.

European Commission, (2015). Energy Union Package. A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy Brussels, 25.2.2015 COM(2015) 80 final.

European Commission, (2016). Accelerating Clean Energy Innovation. Brussels 30.11.2016. COM(2016) 763 final.

European Commission, (2018). A clean planet for all. A European strategic long-term vision for prosperous, modern, competitive and climate neutral economy. Brussels, 28.11.2018. COM(2018) 773 final.

García-Quevedo, J. (2018), "I+D e innovación en energía" en J. L. García Delgado, J. C. Jiménez y J. Batalla (Eds.): Desafíos del sector energético: Un enfoque sectorial. Thomson Reuters.

GEA, (2012). Global Energy Assessment. Towards a sustainable future, Cambridge University Press, Cambridge, UK and New York, USA.

Henderson, R. M., Newell, R. G., (2011). Accelerating Energy Innovation: Insights from Multiple Sectors. University of Chicago Press.

Jamasb, T., Pollitt, M., (2015). Why and how to subsidise energy R&D: lessons from the collapse and recovery of energy innovation in the UK. Energy Policy 83, 197–205.

Newell, R. G., (2010). The role of markets and policies in delivering innovation for climate change mitigation. Oxford Review of Economic Policy 26, 253-269.

Molero, J., (2012). La importancia económica de innovar en el sector de la energía. Cuadernos de Energía 34, 77-83.

OECD, (2002). Frascati Manual: Proposed standard practice for surveys on research and experimental development. OECD, Paris.

OECD, (2005). Oslo Manual. The measurement of scientific and technological activities. Proposed guidelines for collecting and interpreting technological innovation data. 3rd Edition. OECD Publishing.

Sanyal, P., Cohen, L. R., 2009. Powering Progress: Restructuring, Competition, and R&D in the U.S. Electric Utility Industry. The Energy Journal 30, 41-79.

Wiesenthal, T., Leduc, G., Haegeman, K., Schwarz, H.-G., (2012). Bottom-Up estimation of industrial and public R&D investment by technology in support of policy-making: the case of selected low-carbon energy technologies. Research Policy 41, 116–131.

OVERVIEW OF THE SITUATION IN PORTUGAL. ELECTRICITY IN PORTUGAL: A SMOOTH PARADIGM SHIFT

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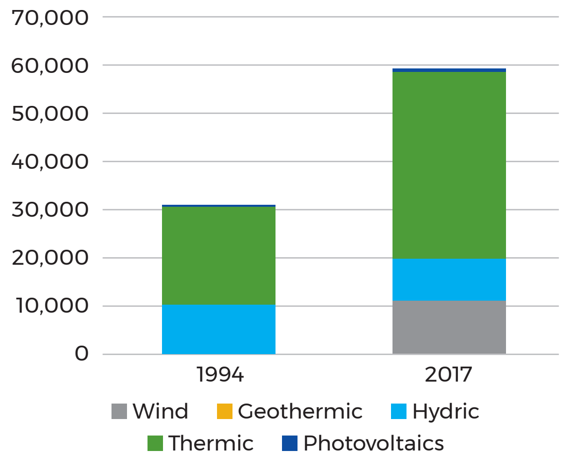
INTRODUCTION

Portugal had a state monopoly for the transport, distribution and commercialization of electricity, as well as the various hydroelectrical and/or coal centrals, until 2000. Since then, there was a separation between the incumbent operator, EDP, and the newly created transmission system operator, REN, which has the monopoly of the operation of electricity and natural gas networks. Both were 100% privatized. EDP's main competitors are large Spanish operators. Portugal has seen a strong emergence of renewable energies, mainly hydric and wind, with the incumbent EDP playing a major role, but is lagging in solar. Portugal has a very strong position as regards sustainable mobility, with electric cars penetration being the 4th highest in the EU. The Government has a reliable plan for the horizon 2021-2030 for the decarbonization of the economy and for the consolidation of renewable energies.

ELECTRICITY PRODUCTION AND CONSUMPTION IN PORTUGAL

The most recent data [1] on energy sources shows that in 1994, 25 years ago, production of electricity power in Portugal was of 31 TWh (Figure 1) while consumption was of 28 TWh (Figure 2). In a quarter of century, production increased to 59 TWh while consumption amounted in 2017 to 48 TWh.

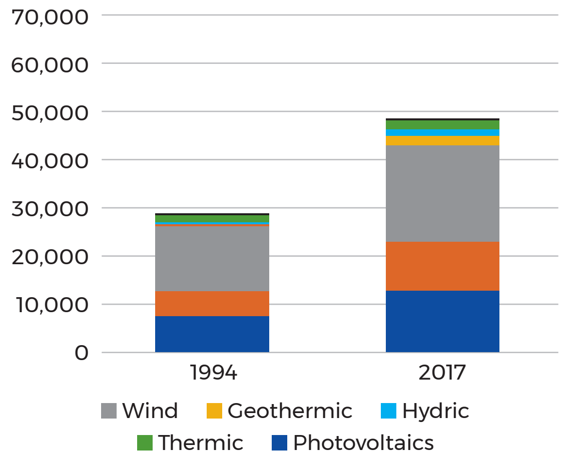
FIGURE 1. ELECTRICITY PRODUCTION BY SOURCE [GWh]



Source: www.pordata.pt

The production of electric energy was based in 1994 on two sources: hydroelectric, which accounted for 1/3, or less, of total, and thermic, 2/3 (Figure 1). While these figures have varied substantially year by year, the actual trend has been a sound decline on the hydro quota, which

FIGURE 2. ELECTRICITY CONSUMPTION BY SECTOR [GWh]



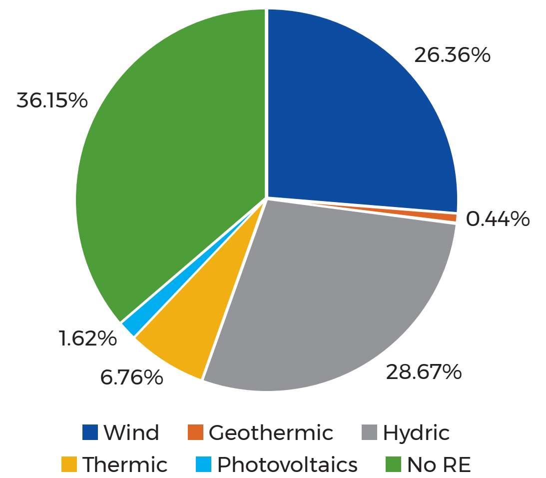
Source: www.pordata.pt

was as low as 13% in 2017, and a smaller decline on thermic sources, which was for the 1st time below 50% in 2014 (44%). Meanwhile, the renewable sources have slowly but steadily improving their contribution, which approached 10% in 2007, with wind sources representing more than 20% since 2012, and photovoltaics (PV) almost 2% in 2017.

The most recent statistics from the Portuguese official Statistics Office (INE) [2] point to wind representing in the 5 latest years always more than 25%, and in 2017 more than 26%, photovoltaics more than 2% and the set of renewable sources amounting in most of the latest years to close to 70% of final consumption of electric energy (Figure 3). The large variations in hydric and thermic share are due to the quantity of rain each year, making the hydric contribution very erratic, and might jeopardize the commitment with the EC of Renewable Energies (RE) to represent 60% (as a weighted average of the latest 15 years) of all electric consumption in 2020 [3]. The RE sources have had received significative incentives from the Government namely as of 2007 [4].

According to the former President of the national regulator for the energy sector (ERSE), the wind capacity was at the end of 2017 of 5090 MW (247MW in 2003), which corresponds to 26% of both the global electroproduction capacity in the Continent, which was of 19800 MW, and of the final electricity consumption in the same year (Figure 3). These figures were well above the EU average of 14% and 9% respectively, in 2015 (Vasconcelos, 2019). According to the same author, on the other hand, solar capacity was of 852 MW, 4.3% of total, which compares to a global EU average of 9.7% in 2015. Actually, in 2015, the solar based electrical production, 1.7%, in Portugal (Figure 3) was under EU average (3.3%) and well under the other Southern European countries, such as Spain (4.9%), Greece (7.5%) or Italy (8.1%), and it was even inferior to Germany (6.0%) (Vasconcelos, 2019).

FIGURE 3. RE CONTRIBUTION FOR ELECTRICICTY FINAL CONSUMPTION 2013-2017 (%)



Source: Spanish Institute for Statitstics (INE) [27]

The total electricity consumption reached a peak of more than 50 TWh in 2010 and has declined significantly to 46 TWh in 2014, having recovered slowly since then. This is mostly due to the economic crisis and the fall in economic activity and has increased since then due to a mild economic recovery. Consumption per segmented unit shows stable figures for the home consumers, while each economic unit spends typically more energy per year, particularly in Industry and mostly Agriculture.

ORGANIZATION OF THE ELECTRICITY SECTOR IN PORTUGAL

The electricity sector in Portugal was traditionally organized since 1975 as a state monopoly as Electricidade de Portugal (EDP), a 100% Government owned firm, was the sole provider of electricity to home and industrial sectors, and was the owner, together with the Government, of both the transport, distribution and commercialization networks, as well as the various hydroelectrical and/or coal centrals.

In the year 2000 the Government separated the transport network from EDP, creating Rede Elétrica Nacional (REN), the Transmission System Operator (TSO) [5]. REN, which owns the transport networks of both Electricity and Natural Gas, was privatized in successive tranches between 2007 and 2014 [6]. EDP had been partially privatized since 1997 and it was fully privatized as of 2011 [7]. Meanwhile, as the dimension of the national market was small, Portugal, together with Spain, created in 1998 an integrated market for the two electric systems in the Iberian Peninsula, the MIBEL [8].

Liberalization of the market was complete in 2006, in a process which lasted since 1997. On April 2019 the liberalized market represented only 94% of all the electric market, as regulated market clients have still until the end of 2020 to move into the liberalized market, and 6% of total consumption was still made in the regulated market [9].

EDP has a share of 42% of final consumption, and the two big Spanish operators, Iberdrola and Endesa, have 17% each. GALP, with 7%, and the smaller Spanish operators Fortia with 3%, Acciona and Fenosa, with 2% each, make more than 90% of the market. Iberdrola and Endesa lead in the major accounts and Industry sectors, with EDP having a significant position in these segments as well. EDP leads comfortably in the home segment. The importance of the incumbent, EDP [10], in the electric sector can be seen in Table 1.

TABLE 1: EDP CONSOLIDATED (2017)

Clients: 11.5Mn	9,9 Electicity
Market Cap: € 10Bn	1,6 Natural Gas
EBITDA: € 4Bn	
Generation Cap: ~ 26.8GW (73% renewables)	
GENERATION & SUPPLY	
IBERIA 17% of EBITDA Generation Cap. – 13.6 GW in Portugal and Spain (7.1GW is hydro) 5.5M electricity .7 Natural Gas	**EDP RENEWABLES** 39% of EBITDA Generation Cap. (Wind & Solar Power) - 10.7 GW
EDP BRASIL 17% of EBITDA Generation Cap. - 2.5 GW (1.7 GW is hydro)	**REGULATED NETWORKS IBERIA** 27% of EBITDA

Source: EDP Group

In terms of RE, the list of the most important firms belonging to the Portuguese Association of Reneweable Energy (APREN) [11], which represents more than 90% of all RE based Electricity, can be seen in Table 2.

TABLE 2: RENEWABLE ENERGIES MAIN PRODUCERS (APREN)			
	Energy	**Production**	**Country of origin**
Acciona Energia Portugal	Wind/sol	165,6	Spain
Brookfield renewable	Wind	123,1	North America
EDF EN	Wind	235	France
EDP GPE	Hyd/Sol/Wind	6891	Portugal
EDP Ren	Wind/Sol	1301	Portugal
Finerge	Wind	742,5	Portugal
Generge	Hyd/Sol/Wind	488,5	Portugal
Iberdrola	Wind	92	Spain
Iberwind	Wind	726,1	Portugal
Lestenergia	Wind	143,8	Portugal
The Navigator company	Bio/Sol	488,5	Portugal
Trustwind	Wind	488,5	France/Japan
TOTAL: 11,885.6 MW			

Source: APREN

The market for RE is thus fragmented, with local and foreign operators. Most of the solar operators are not in this list, as they are very dispersed and mostly operating in a relatively small scale. As mentioned above, this is precisely the portion of RE which has the biggest upside, as it still represents a very minor share of electric production.

R&D AND INNOVATION

Energy was defined as 1 of 15 thematic priorities of ENEI (Estratégia Nacional de Investigação e Inovação para uma Especialização Inteligente 2014-2020" (Portugal RIS3 2014-2020), in four axes, all of them very relevant for the electric sector [12].

1- Optimization of energy production and transportation and complementarity in their management (renewable, non-renewable, new fuels and hydrogen, fuel cells, nuclear fusion, CO2 capture and storage, real-time energy system management, storage systems power).
2- End-use of energy, energy efficiency and its impacts (Smart Cities, NZEB Net-Zero Energy Buildings, energy in transportation, consumption patterns and consumer behaviour, electricity and natural gas distribution, climate change).
3- Applications of new technologies and smart energy networks (ICTs, Smart Grids).
4- Integration of the European energy market (modelling, planning, new market models, regulation.

R&D in the energy sector evolved from 100 M€ in 2014 to 106M€ in 2016 (Table 3). Expense is almost evenly spent between firms, with 44% of the expense, and the Higher Education institutions (Universities and Polytechnic Institutes), with 47%, Government with the remaining 9% [13].

This data on R&D on the Energy sector is, nonetheless, in conflict with the information gathered from national statistics sources on NACE 35 [14]. Electric

TABLE 3: R&D BY ENEI THEMATIC AREA (2014 to 2016). Unit K€							AVERAGE	
	2014		2015		2016		2014-2016	
Energy	99.799		103.209		105.667		102.892	
Firms	46.009	46%	43.290	42%	46.880	44%	45.393	**44%**
Higher Education	46.291	46%	50.175	49%	49.632	47%	48.699	**47%**
Government	7.479	7%	9.745	9%	9.155	9%	8.793	**9%**
Portugal Total R&D	2.232.249	**4,5%**	2.234.370	**4,6%**	2.388.467	**4,4%**	2.285.029	**4,5%**

Source: DGEEC

power generation, transmission and distribution (including trade) are inside this class, but they are not the only ones [15]. Using this NACE class as a proxy for Electricity sector we find in the annual enquire to the national Science & Technology potential (IPCTN) 2017 [16] that NACE 35 R&D performed by firms was of only 4M€ in 2017. This supposes an entrepreneurial R&D intensity (firms R&D/Gross Value Added) for NACE 35 of 0.10%, which compares with 0.67% for the whole of the economy.

This is reinforced with the findings of the Community Innovation Survey for 2016 [17], where we notice that only 51% of the sector's firms perform any innovative activity, which compares to 64% for the whole of the economy. If we narrow the analysis to product or process innovation, figures come down to NACE 35 with 49%, versus National with 57% of innovating firms. The bright side is that 30% of the firms which innovate in NACE 35 perform R&D activities inside the firm and 20% acquire it, versus global figures of 19% and 11%. Summing up, these firms innovate less, but half of those which do, pursue R&D activities internally or buying them, which compares to 30% in the National economy.

The most important R&D units are naturally linked to the main network operators, EDP and REN.

EDP Innovation is the Innovation branch of EDP [18]. With 32 collaborators, it has more than 2500 applications running, 27 pilot projects and an accumulated investment in R&D (2017 figures) of 26M€ and has 41M€ yearly revenues (2017). Its R&D and Innovation activities focus is on 5 areas:

1- Cleaner Energy: Renewable Energy and Thermal & Big Hydro Generation, comprising Wave energy (HAWE), new solar technologies, offshore wind, onshore wind, solar PV and solar CPS; estimation of wind turbine life estimation.
2- Smarter Grids: Smart Grids Infrastructure (decentralized and hybrid) and Energy Distribution Management.
3- Data Leap: Cloud Computing, Big Data and Advanced Analytics, reconciling energy purchased from producers and energy sold to consumers, aggregated by retailer, performing aerial line inspections and predictive maintenance; Web 3.0, Internet of Things, creating low-cost solutions for monitoring home energy consumption.
4- Energy Storage: Battery Technologies and Storage Management and Control, namely by Vehicle to Grid (V2G)

innovation, using Electrical Vehicle (EV) power battery to support the grid through decentralized flexibility and by innovating on the use of depleted EV batteries for grid applications, reusing them for a 2nd life.

5- Client-Focused Solutions, such as Smart Pricing and Bundling and Energy Efficiency, changing the relationship between EDP and this new energy consumer. The area proposes to focus in four main streams: smart home & smart energy, electric mobility, digital customer engagement and innovative business models, and increase electrification.

Smart metering has been slowly introduced by EDP since 2007, using 4.5 G technology, in the electricity network consumers premises. EDP had a 60% target for 2020 and it is estimated that in 2018 1.3 million smart meters were functioning. By law, the objective now is 100% coverage by 2022.

REN, the TSO, is the other big player in R&D in the electricity sector, with R&D Nester [19]. Just as EDP Innovation, NESTER invests in a new paradigm which combines energy from renewable sources, with a distributed generation, smarts grids and demand side management with new storing technologies and EV.

Another important player is Efacec, a Portuguese Industrial provider with a very relevant role in the field. It provides turn-key projects across the Energy sector, comprising electricity production centrals of all types (Thermic, hydric, biomass, wave, wind and solar) and is the world leader in the field of fast and ultra-fast EV charging stations, while performing also the integration

TABLE 4: LOW CARBON ENERGY PATENTS

WIND	Nº	Solar	Nº	Waves	Nº	Biomass	Nº	Hydric	Nº	Geothermic	Nº	Other	Nº
Wind	30	Solar	94	Waves Energy	45	Biomass	3	Hydric	5	Geothermic	2	Hydrogen production	21
Air generator	3	Solar Coletor	25	Tide Energy	8	Biofuel	6	Hydraulic Energy	8	-		Energy storage	27
Wind Turbin	18	Solar panel	26	Ocean Energy	1	Biodiesel	8	-					
		Solar thermic	16	Sea stream	4	Bioethanol	4						
		Solar PV	4	Hydaulic Turbin	3	Biogas	6						
		CSP	5	Moving water column	3	Bio-methane	2						
Wind	51	**Solar**	170	**Waves**	64	**Biomass**	29	**Hydric**	**13**	**Geothermic**	**2**	**Others**	**48**
TOTAL: 377													

Source: Instituto Nacional de Propriedade Industrial (INPI), in PNEI 2021-2030

in management systems for efficient use of electric grid infrastructure [20].
There is an interesting stock of active patents registered in the National Intellectual Property Office (INPI), which have been submitted in the last two decades (Table 4) [21].

The number of Solar patents reinforces the envisaged growth of the contribution of the solar technologies to electric production. The Government is no longer subsidizing solar panels in private buildings, but it is expected that the development of solar technologies, particularly Concentrated Solar Power (CSP/CST technologies), will foster solar contribution.

MOBILITY

A good example of a mix of policy, R&TD and Innovation, is Mobility, and MOBI.e. Portugal was in 2011 one of the pilot sites of the EU project MOBI.E [22]. The project was able to build a network of 400 public charging stations. This big infrastructure, which was of free use, was almost abandoned, practically with no maintenance, during the crisis period in Portugal, but has been revived and widened under the new Government. It is fully operational, it is now composed of 960 public charging stations, it has been of widely used and it has performed more than 1 million charges, for more than 10 thousand registered cars, free of charge. As of April 2019, stations located in private places could opt for charging a payment for each car's electrical charge. This had been the case as well, as of November 2018, to fast charging stations (20-30 min for 80% capacity) only. Inteli, a local Innovation centre, was at the heart of the project, together with a couple of software companies, Renault, and two of the above referred companies, EDP Innovation (R&D) and Efacec, which supplies most of the charging stations. On the other hand, Government offers in 2019 a 3.000€ (2.250€ in 2018) subsidy to each consumer for the acquisition of an electric car (electric bikes 250€ and motorbikes 400€) [23].

The success of this policy could be shown by the figures published by the European Automobile Manufacturers Association [24], on May 6, 2019.

TABLE 5: ECV PENETRATION
unknow for Croatia, Cyprus, Luxembourg and Malta

Country	ECV share (%)	GDP/capita/10^3 €
Sweden	8	47,9
Netherlands	6,7	44,6
Finland	4,7	42,2
Portugal	3,4	19,5
Austria	2,5	43,6
UK	2,5	37,6
Belgium	2,4	39,6
Denmark	2,1	54,4
France	2,1	36,2
Germany	2	41
Ireland	1,6	63,4
Hungary	1,5	14,2
Slovenia	0,9	22,4
Spain	0,9	26,2
Bulgaria	0,6	8,1
Latvia	0,6	14,9
Estonia	0,5	18,8
Italy	0,5	29
Romania	0,5	10,8
Czhech	0,4	20,5
Lithuania	0,4	15,9
Greece	0,3	17,1
Slovaquia	0,3	16,6
Poland	0,2	12,9
EU 24	**1,9**	**29,1**

Portugal, with a 3.4% ECV penetration (Electric cars/Total cars), ranks 4th in the EU, second only to Sweden, Netherlands and Finland, and well above the average EU penetration, 1.9 (Table 5). This places Portugal 80% above the average penetration in the EU, although Portugal's GDP per capita is 33% under the average. By comparison, France's current penetration is 2.1 and Spain's is only 0.9%.

CURRENT SITUATION AND POLICIES. STRENGTHS AND WEAKNESSES

The Government analysis of the Energy situation is part of the Plano Nacional Energia e Clima (PNEI) 2021-2030 [25], which results from complying to the Regulation (EU) 2018/1999 (European Parliament) and of the European Council decision of 11 December 2018, concerning the governance of the Energy Union and climate change, in order to guarantee that the European Union is carbon neutral in 2050, thus contributing to limiting the increase of the global temperature to 2° if compared to the pre-industrial levels [26], on its 5 axes:

1- Security
2- Internal energy market
3- Energy efficiency
4- Decarbonising and research
5- Innovation and competitiveness

The Government targets a 25% energy efficiency gain in 2020 and 35% in 2030, relatively to 2012, and later updated in 2016, figures. The target for the weight of RE in the global energy consumption is of 47% in 2030. The weight of RE in the production of electricity should be of 68% in 2020, 76% in 2025 and 80% in 2030. Coal fuelled centrals will all be shut by 2030. Electrification of the whole economy is being pursued and electric mobility is strongly supported.

PNEI defines the areas that R&TD and Innovation national programmes on the Energy sector should cover:

1- Smart systems of energy management and new infrastructures, considering the foreseen big increase of RE and a new and more decentralized energy production paradigm.
2- Energy storage, considering the foreseen big increase of RE.
3- Low carbon technologies, such as the RE described earlier: off shore wind, next generation PV, CSP, wave energy and deep geothermic energy.
4- Energy efficiency, particularly in Industry and buildings.
5- Hydrogen as an energetic vector.

From everything stated above, we might say that Government recent policies and plans are vigorous and focused on the decarbonization of the economy and on the wide adoption of renewable energies. The separation of the TSO from the incumbent distribution operator, which is still the largest in the market, and is investing immensely on RE, are strong points. The growing importance of RE suggests EU challenges and goals for 2020 and 2030 will be attained. Figures for mobility showing that Portugal is very close to the forefront of EU reinforce this perception. On the negative side, the lack of a strong set of industrial partners as well as a clear lag in solar production, which is not acceptable in such a sunny country, are clear weaknesses.

BIBLIOGRAPHY:

Vasconcelos, J. (2019) A energia em Portugal. Fundação Francisco Manuel dos Santos.

REFERENCES:

1. https://www.pordata.pt/Homepage.aspx
2. https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&contecto=pi&indOcorrCod=0007273&selTab=tab0
3. http://www.energiasrenovaveis.com/DetalheNoticias.asp?ID_conteudo=966&ID_area=23
4. http://www.erse.pt/pt/electricidade/actividadesdosector/producao/Paginas/default.aspx?master=ErsePrint.master
5. http://www.erse.pt/pt/imprensa/comunicados/2000/Comunicados/comunicadodeimprensa_separacaoentreareneogrupoedp.pdf
6. https://www.jornaldenegocios.pt/mercados/detalhe/estado_encaixa_157_milhoes_com_privatizacao_da_ren_pouco_concorrida_por_pequenos_investidores
7. https://www.edp.com/pt-pt/investidores/acao-edp/privatizacao
8. http://mibel.com/en/home_en/
9. http://www.erse.pt/pt/electricidade/liberalizacaodosector/informacaosobreomercadoliberalizado/2019/Comunicados/201901_ML_elec.pdf
10. https://portugal.edp.com/en/
11. https://www.apren.pt/pt/associados/junte-se-a-nos
12. http://www.dgeec.mec.pt/np4/206/%7B$clientServletPath%7D/?newsId=948&fileName=DGEEC2018_DespesaIDPorAreaTematicaENEI.pdf
13. http://www.dgeec.mec.pt/np4/206/%7B$clientServletPath%7D/?newsId=948&fileName=DGEEC2018_DespesaIDPorAreaTematicaENEI.pdf
14. Statistical classification of economic activities in the European Union.
15. Electricity, gas, steam and air conditioning supply.
16. http://www.dgeec.mec.pt/np4/206/
17. http://www.dgeec.mec.pt/np4/207/
18. https://www.edp.com/en/edp-innovation
19. http://www.rdnester.com/
20. https://electricmobility.efacec.com/
21. https://ec.europa.eu/energy/sites/ener/files/documents/portugal_draftnecp.pdf
22. http://www.veiculoselectricospt.com/mobi-europe/
23. https://www.fundoambiental.pt/avisos-2019/incentivo-pela-introducao-no-consumo-de-veiculos-de-baixas-emissoes-2019.aspx
24. https://www.acea.be/statistics/article/interactive-map-correlation-between-uptake-of-electric-cars-and-gdp-in-EU
25. https://ec.europa.eu/energy/sites/ener/files/documents/portugal_draftnecp.pdf
26. https://ec.europa.eu/commission/priorities/energy-union-and-climate_en.
27. https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0007273&contexto=bd&selTab=tab2

OVERVIEW OF THE SITUATION IN FRANCE, R&D AND INNOVATION IN ENERGY

Cecilia Hinojosa (Toulouse III University Paul Sabatier) and Thierry Talbert (PROMES-CNRS Lab – Perpignan Via Domitia University)

INTRODUCTION

The issues and challenges of global warming require us to rethink the way we produce and consume. The goal is to develop new growth models, particularly those of sustainable growth in a more energy-efficient and less nuclear and fossil fuels-dependent society. During the COP21 held in Paris in 2015, the need for governments and businesses to support innovations in favour of low-carbon technologies was recognized in order to limit the rise in global average temperatures. To do so, two major international initiatives were launched in 2015: the "Innovation Mission" and the "Breakthrough Energy Coalition" with the aim of accelerating innovation and stimulating and directing investments in clean energy to fight against climate change. The support system for French R&D fits into this framework by concentrating its efforts on renewable energies and energy efficiency.

SUPPORT AND PUBLIC INVESTMENT IN ENERGY R&D IN FRANCE

French research and innovation policies have undergone profound changes in recent years. Since 2013, policies have been geared towards developing more coherent systems, which aim to strengthen public-private partnerships and optimize the use of human and financial resources. The model chosen by France to support research and innovation is based on indirect support schemes, accounting for 70% of public support for R&D in 2013 (OECD, 2016).

Strategy

In the fight against climate change, the search for new means of energy production is based mainly on R&D and innovation. These factors are therefore essential elements in the transition to "green growth". In this context, France established a National Strategy for Energy Research (SNRE) with the aim of guiding the technological and societal choices necessary for a "green and sustainable growth". This strategy was established through the law relating to the energy transition for green growth (LTECV) and by ratifying the Paris Agreement signed at the end of COP21. This strategy is based on the National Low Carbon Strategy (SNBC) and the

Multiannual Energy Program (EPP). It has been developed in line with the main National Research Strategy (SNR) guidelines for energy.

At the centre of the strategy, all the pillars of the energy policy and all types of energies are involved: control of energy demand, control of energy costs, promotion of renewable energies, guarantee of security of supply and energetic independence, etc. This means that it is possible to build a coherent and complete vision of the place of energies and their desirable evolution in French society.

In France, there are several financing and/or research incentive systems for public and private institutions (the figure below illustrates such financing systems).

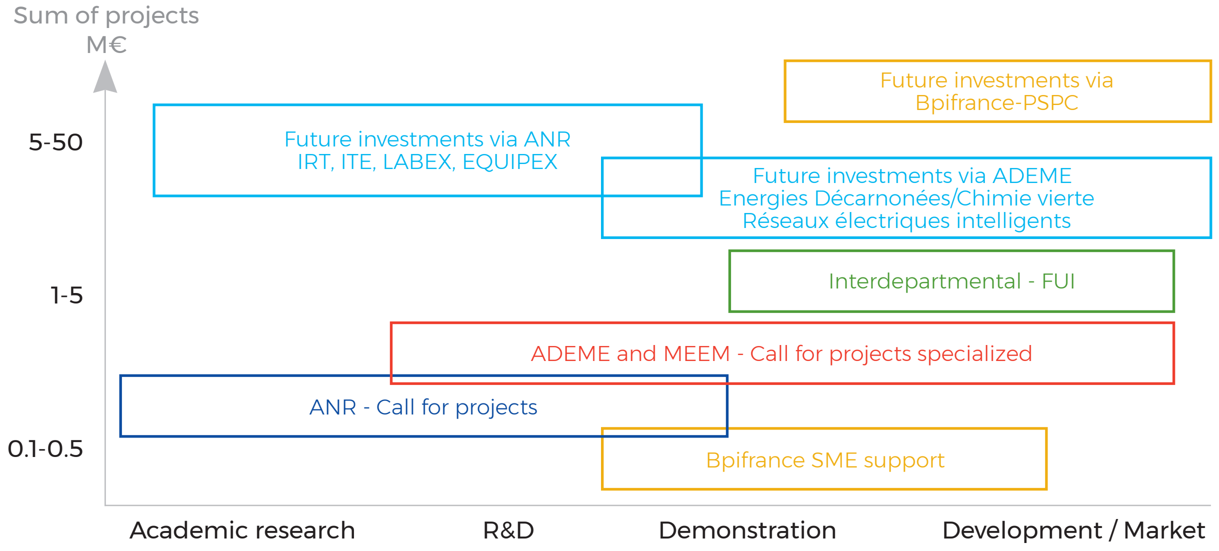
France supports collaborative research projects between public and private R&D players, and innovative projects through the Investments for the Future Program (PIA) while at the same time supporting the innovative projects of companies with a budget of 22 billion euros for higher education and research. The financing of these different projects is done throughout the innovation chain and through different national systems.

At the same time, in the field of energy, there are four main actors involved in the promotion of innovative solutions which will be briefly described below:
- ANR: National Research Agency
- Agency ADEME: French Environment & Energy Management Agency
- CRE: Commission for Energy Regulation

National Agency for Research

The National Agency for Research (ANR) is the French agency for financing project research, for public operators cooperating with each other or with companies through various financing means.

FIGURE 1. MAIN NATIONAL SUPPORT PROVISIONS FOR INNOVATION
Positioning of the main current national incentive schemes along the energy innovation chain



Source: National Strategy for Energy Research, December 2016

The ANR operates a funding program for basic research through calls for target projects whose priorities are defined by the national research strategy. In the field of energy, 5 axes were defined:
- Dynamic management of energy systems
- Multi-scale governance of energy systems
- Energy efficiency in all sectors of the economy
- Reduced need for strategic materials
- Decarbonation of energy and chemistry

At the same time, the ANR is responsible for steering the Institutes for Energy Transition (ITE). The actions carried out aim to constitute technological innovation campuses of reference in the new technologies linked to energy and by gathering companies and laboratories. These public-private research centres constitute a structuring base for research and innovation activities in the following fields:
- Green chemistry and agro-based materials: PIVERT
- Solar energies: IPVF and INES2
- Electrical networks: SUPERGRID
- Energy efficiency and sustainable cities: EFFICACITY
- Sustainable building: INEF4
- Decarbonised and connected vehicles: VEDECOM
- Marine renewable energies: France marine energies
- Geothermal and underground technologies: Géodénergies

ADEME

The French Environment and Energy Management Agency (ADEME) participates in the implementation of public policies in the fields of environment, energy and sustainable development. It acts as operator of the PIA on strategic topics. In particular, it supports, through State aids such as subsidies and repayable advances, research and innovation demonstrators in the field of carbon-free energy and energy and environmental transition in the following areas:
- Renewable energies
- Decarbonisation of energy uses, energy efficiency
- Storage, energy conversion and smart grids
- Sustainable building, especially energy renovation
- Water and biodiversity
- The circular economy
- New mobility solutions, technologies and transport infrastructure that are more energy efficient and have a lower impact on the environment.

CRE

The Commission for Energy Regulation (CRE) is an independent administrative authority. Its missions are divided into two parts: First, to contribute to the proper functioning of the electricity and natural gas markets for the benefit of consumers and in coherence with the goals of the energy policy and second, to regulate gas and electricity networks, which are monopolies, setting their tariffs and ensuring that they do not favour any particular users. With regard to research and innovation, its mission is to implement renewable energy support schemes by issuing invitations to tender.

Public actors

The main actors intervene throughout the entire R&D value chain and are supported through the various R&D

support mechanisms. Basic research is carried out mainly by public laboratories including the Scientific Research National Centre (CNRS). Industrial research and research demonstrations are notably carried out by public establishments including the Commissariat for Atomic Energy and Alternative Energies (CEA), the Scientific and Technical Centre for Building Construction (CSTB) and IFPEN Energies Nouvelles, a former Institute. French Oil. There are other structures that can participate to a lesser extent in the development of smart-grids such as the Bureau of Geological and Mining Research (BRGM).

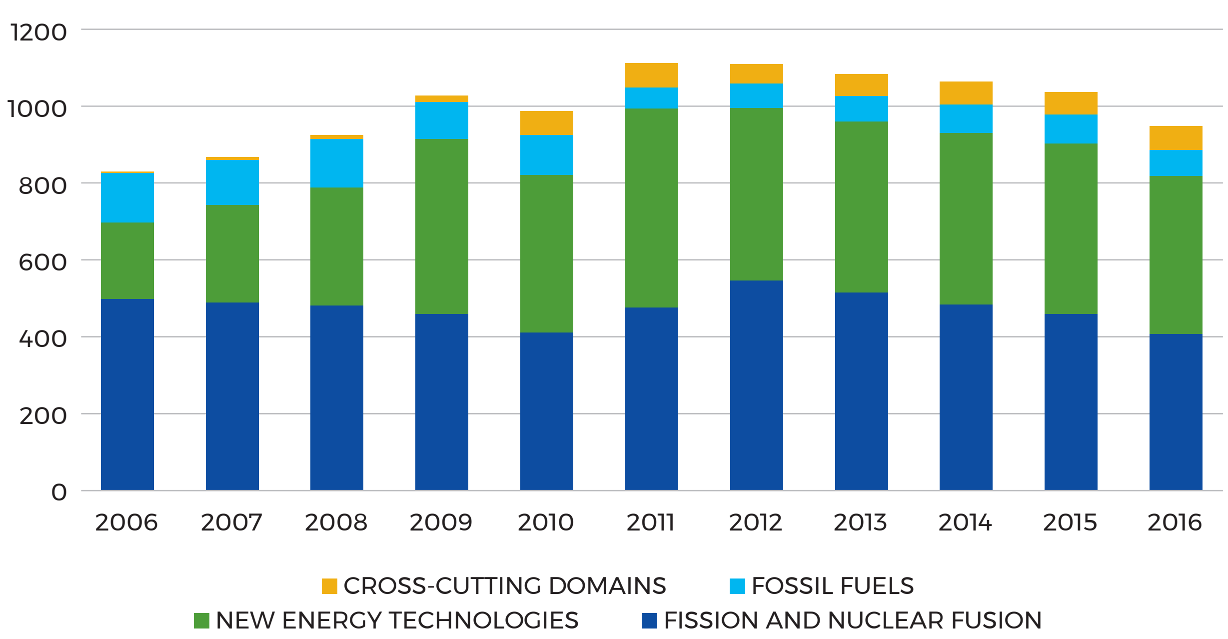
Investment

The energy-related challenges of new production methods (variable and distributed sources of renewable energy), consumption (proactive role of consumers, energy efficiency, etc.) of transport and storage (smart grids etc.) and the question of energy by 2050 and beyond require significant investments, major research and development (R&D) while accompanying existing channels and new channels to maturity and development, and the competitiveness needed to meet these challenges and achieve a control of the energy mix.

In this context, according to OECD data, in 2018, France spent 2.2% of its GDP on gross domestic R&D (expenditure of enterprises, higher education institutions and research organizations), which is slightly above the European average (2%). At the investment level of R&D for energy, France remains in the lead, with an investment of 0.5% of GDP, according to the IEA.

Regarding public spending on energy R&D, a considerable effort has been made. For example, 944 million euros were invested in 2016 with the aim of investing mainly in new technologies in the field of energy, nuclear energy, fossil energy and cross-cutting research areas, as shown in the graph below.

FIGURE 2. PUBLIC SPENDING ON ENERGY R&D (MILLION EUROS)



Source: MTES/CGDD. https://www.ecologique-solidaire.gouv.fr/recherche-et-developpement-lenergie

INNOVATION STRATEGIES OF ENERGY COMPANIES

From all the previous information, it is possible to distinguish two major groups of innovation strategies related to companies:

- Strategies that are directly related to different research programs (PIA, ADEME, ANR, to a lesser extent the CRE)
- Strategies allowing a certain flexibility to innovation (CRE), to see a total freedom (Unique Inter-ministerial Funds and Regional Funding)

In the first case, that of the guidelines being defined by the state, we find all the projects developed in recent years concerning smart grids developed by EDF, RTE, Siemens, Schneider Electric (non-exhaustive list). The common goals that can be found are:

- The integration of renewable energies into the network: The choices generally focused on local energy productions at the neighbourhood and/or city level (Projects: NiceGrid, Lyon Smart Community, Grenoble Ecocity, Premio, Kergrid, Elhyrat, etc.).
- Local energy management: In accordance with the previous and the following point (Linky), a number of projects have dealt with local energy management with or without intervention of the operation of the different consumption systems according to constraints of price, reliability, etc. (Projects: GreenLys, Vir'Volt, Rennes Grid, Nice Sophia Antipolis Smart Campus, etc.).
- The development of a local energy metering system (Linky) and its integration with local and regional energy management (Projects: Reflexe, Watt & Me, GridTeams, A Bretagne in advance, Val d'énergie, Janus, etc.).
- The integration of electric vehicles into the network. The building energy management and the gas transformation are also part of the various points that we find in the developments (Projects: Greenfeed, Telewatt, Jupiter 1000, Demeter, Move in pure, Pushy, Show it, etc.).

In addition to national objectives, some projects have attempted to respond to local problems. We can take as a typical example the problem of managing in Brittany at the peak of consumption (Projects: Enbrin, Address, Local Energy Loop - Brest right bank, Operation Vir'Volt, A Bretagne in advance, etc.).

In the second case, there are a number of programs funded by the FUI / ERDF / Regions or own funds which address particular points of research around smart-grid. We can mention the projects RIDER, Primergi, Oslo2Rome and DataZero among others. These projects dealt with:

- Problems that are not present in the national recommendations but that appeared later. This is the case of the RIDER project which dealt with the management of the fatal energy of data centres for the realization of a heat loop for the thermal management of commercial buildings. And the case of DataZero that has issues that are not covered by national recommendations. This is the case for the PRIMERGI and Oslo2Rome projects, which have proposed solutions for the management of faults in PV installations (individual and high power) and the decentralized processing of electrical energy management information including the use of electric vehicles, respectively.

For the upcoming years we can distinguish the following objectives:

- Decentralization of energy systems, namely the possibility of intelligently managing the distribution of renewable energy sources throughout the territory, and in particular local production but also self-consumption.
- The territorialisation of energy policies: In a context of increasing decentralization (through the law relating to the Energy Transition for Green Growth (LTECV), National Low Carbon Strategy (SNBC) and the Multiannual Energy Program (EPP)) the territories (city, agglomeration, department, region) are forced to propose local energy policies (Regional Development, Sustainable Development and Equality of the territories known as SRADDET). In particular, the Occitania Region is at the forefront of this trend by setting itself the goal of becoming the first energy positive region in Europe by 2050.
- Decarbonization of the energy mix: France is committed to reducing its GHG emissions by 75% by 2050 compared to 1990 (Factor 4, National Low Carbon Strategy). Although France already has a relatively decarbonised energy mix in comparison with other European economies, the challenge of maintaining a decarbonised mix is reflected in the commitments of the Energy Transition law for Green Growth (LTECV) and the orientations of the Multiannual Energy Program.
- Similar to the previous point, specific local traffic control systems depending on the type of engine are in place, in addition to the national orientation. We can mention, for example, the Air Protection Zones (ZPA) and the Regulated Circulation Zones (ZCR), with the dual objective of reducing emissions of CO2 and harmful pollutants (NOX, fine particulate matter). The agglomerations of Toulouse and Montpellier, with competitiveness clusters DERBI, have a 4-year strategic roadmap for innovation in their respective ZPA.
- Digitization of energy systems: All the sensors that have been and/or are deployed in electrical, residential, gas water, etc., allow data collection, which is growing exponentially. Information can therefore be processed, analysed and made available to optimize the management of energy systems from production to final consumption. Digital technologies must make new services possible for all stakeholders in energy systems: planning, monitoring the implementation of policies and identifying needs for policy makers (for example, local and regional authorities), improved knowledge of resource deposits and productive capacity for project promoters, better anticipation of supply-demand balances for network managers and balance managers, traceability of the non-fossil origin of energy for electricity and gas suppliers, real-time consumption monitoring and recovery services for consumers, etc.
- Changing uses and the role of the consumer: Although the principle of the evolution of the energy system seems to be accepted, it is still often forced by a citizen’s demand not to see its direct environment modified. The contribution of the collected information made available should make it possible to create new services and to modify the behaviour of the end-users.

CONCLUSION

As discussed above, technological innovations in recent years have mainly covered the following topics (non-exhaustive list):

- Integration of renewable energies into the network
- Energy management of the local loop
- Digitisation of information (electricity, gas, water, etc.)
- The coupling of Smartgrid with other sources of information such as transport, risk and electric vehicles
- The detection of defects
- Blockchain of the information processing and management

The financing structure implemented allows to connect the objectives of the local level (city, department and region through regional funding, for example, up to the national level, such as future investment programmes and the national research agency. The interest is to enable a specific local policy to multiply the impact of national policy on local companies. The main lines of research for the next five years were defined by the SNR and completed the previous objectives by:

- Decentralisation of energy management, including the promotion of self-consumption
- The territorialisation of energy
- Decarbonisation of energy mixes
- Digitalisation of information in the big data sense
- The integration of the consumer's role in the energy chain

REFERENCES:

1. This law aims to enable France to contribute more efficiently to the fight against climate change and the preservation of the environment, as well as strengthening its energy independence while offering its companies and citizens access to energy at a competitive cost.
2. The National Low Carbon Strategy (SNBC) describes France's roadmap for achieving carbon neutrality by 2050. It sets targets for reducing greenhouse gas emissions in the medium term by setting carbon budgets that do not exceed five years. OECD Economic Surveys: France © OECD 2019.
3. The Multiannual Energy Program (EPP) presents a strategy for decarbonising France's energy mix for the next ten years: the share of renewable energy will have to reach 32% of final energy consumption by 2030. OECD Studies economic: France © OECD 2019
4. The challenge of the National Research Strategy (SNR) is to respond to the constant challenge of knowledge and the unprecedented socio-economic challenges of our century. In the field of energy, these challenges have been identified in accordance to the European Horizon 2020 program.
5. Organization for Economic Co-operation and Development
6. OECD (2019), Gross Domestic Expenditures on R&D (indicator). doi: 10.1787 / 49ef953e-en (Accessed May 21, 2019)
7. http://www.bsi-economics.org/images/systinnofrance.pdf
8. International Energy Agency (IEA)

TWO PERSPECTIVES ON INNOVATION

INNOVATION FROM A TECHNOLOGICAL PERSPECTIVE

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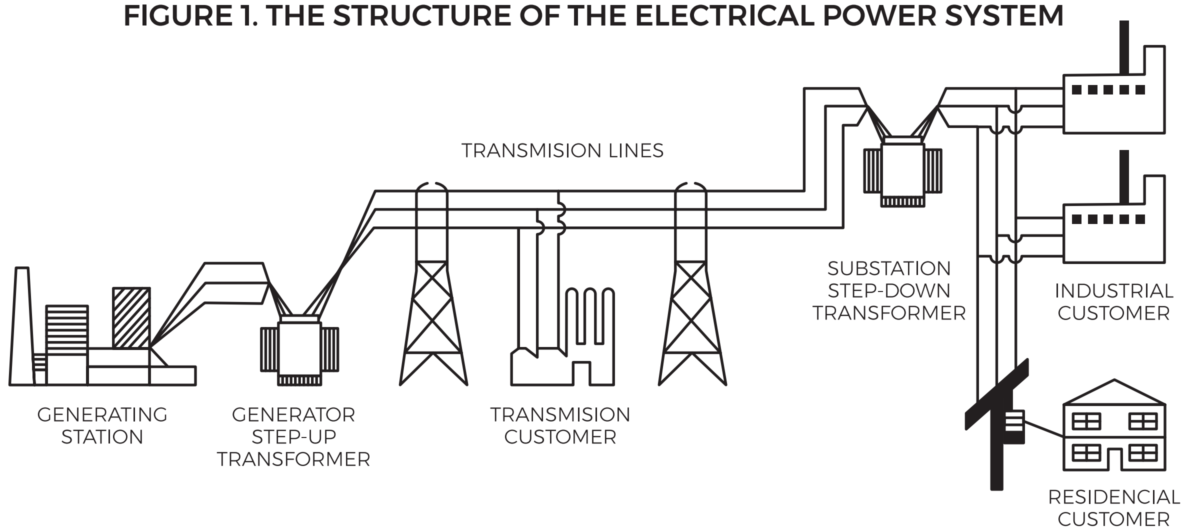
THE CURRENT ELECTRIC POWER SYSTEM

Due to the fact that it is quick and easy to transport and is practically instantaneous to adapt and have available, electric power is becoming an increasingly significant energy vector in all areas of human activity. Electricity currently represents the most useful form of energy and is present in all sectors of society thanks to its wide variety of applications and is also rapidly gaining ground in the important area of transportation.

The current electrical power system (EPS), which meant that the development of society as we know it was possible, has its origins in the 19th century. It is made up of four basic elements: large generators located far from centres of consumption, transport grids that carry energy from generators to consumers, distribution grids that adapt voltage and current values to those required by the consumers, and finally the consumers themselves.

The principal types of generators can be divided into two categories: those

FIGURE 1. THE STRUCTURE OF THE ELECTRICAL POWER SYSTEM



Source: Wikipedia Commons

which use fossil fuels and those which use renewable energies. Examples of the former are nuclear power stations and gas, coal and oil power stations. The latter include hydraulic power stations, wind power plants, general photovoltaic generation and others such as tidal power, hydropower and biomass.

The configuration of the generation systems of Spain, France and Portugal are dissimilar, as can be seen in the following table, which uses data from the ENTSO-E (European Network of Transmission System Operators for Electricity) for the year 2018.

For the purposes of the table and this paper, all hydraulic energy was considered to be of renewable origin. As seen above, Portugal has installed renewable sources for around 68% of its capacity, Spain around 50% and France almost 38%. In all three countries, there is a major effort underway to install new renewable capacity.

TABLE 1. NET GENERATION CAPACITY (2018)

	GWh			%		
POWER	**SPAIN**	**FRANCE**	**PORTUGAL**	**SPAIN**	**FRANCE**	**PORTUGAL**
NUCLEAR	7,117.3	63,130.0	-	6.8	48.2	0.0
FOSSIL FUELS	44,449.4	18,588.2	6,378.8	42.7	14.2	31.9
NON-RENEWABLE WASTE	518.2	-	-	0.5	0.0	0.0
OTHER NON-RENEWABLE	68.5	-	17.8	0.1	0.0	0.1
WIND	23,507.4	15,083.8	5,149.6	22.6	11.5	25.8
SOLAR	7,017.9	8,256.2	558.2	6.7	6.3	2.8
BIO	860.5	1,143.6	658.2	0.8	0.9	3.3
RENEWABLE WASTE	161.5	882.8	-	0.2	0.7	0.0
HYDRO	20,377.6	23,787.7	7,215.0	19.6	18.2	36.1
OTHER RENEWABLE	16.2			0.0		
NON-ENEWABLE	52,153.4	81,718.2	6,396.6	50.1	62.4	32.0
RENEWABLE	51,941.1	49,154.0	13,581.1	49.9	37.6	68.0
TOTAL	**104,094.5**	**130,872.2**	**19,977.7**	**100.0**	**100.0**	**100.0**

Source: own elaboration from ENTSO-E

TABLE 2. ANNUAL ELECTRIC ENERGY GENERATION (2018)

	GWh			%		
POWER	**SPAIN**	**FRANCE**	**PORTUGAL**	**SPAIN**	**FRANCE**	**PORTUGAL**
NUCLEAR	53,197.6	393,100.3	-	20.4	71.6	-
FOSSIL FUELS	102,988.9	39,625.3	25,607.0	39.5	7.2	46.4
NON-RENEWABLE WASTE	2,434.9	2,138.7	-	0.9	0.4	-
OTHER NON-RENEWABLE	28.3	-	228.0	0.0	-	0.4
WIND	49,570.3	27,986.8	12,353.0	19.0	5.1	22.4
SOLAR	12,183.2	10,389.0	820.0	4.7	1.9	1.5
BIO	3,646.5	5,150.3	2,772.0	1.4	0.9	5.0
RENEWABLE WASTE	874.1	2,631.1	-	0.3	0.5	-
HYDRO	36,115.7	68,167.2	13,357.0	13.8	12.4	24.2
OTHER RENEWABLE	23.9	-	-	0.0	-	-
NON-ENEWABLE				60.8	79.2	46.9
RENEWABLE	158,649.8	434,864.3	25,835.0	39.2	20.8	53.1
TOTAL	**102,413.7**	**114,324.5**	**29,302.0**	**100.0**	**100.0**	**100.0**

Source: own elaboration from ENTSO-E

In terms of generation, the following table shows the energy production in each country by technologies. The data is also published by the ENTSO-E.

In 2018 renewable generation in Spain was just over 39%, 53.1% in Portugal and only 20.82% in France, where the principal source of energy is nuclear at 71.6%. In Spain and Portugal, the highest percentage of production corresponds to fossil fuels (coal and gas). Given that there are huge differences between the generation systems in the three countries, drawing common conclusions that can be applied to all of them is complex. However, if we consider the European generation system against a global backdrop and use the data from the ENTSO-E for 2017, it can be seen that in 2017, 65% of the energy produced was of non-renewable origin (41% from fossil fuels and 24% from nuclear) and 35% was from renewable sources (of which 16% was hydraulic). Spain is the country that is closest to the European average while France has the highest percentage of nuclear capacity.

The EPS has been designed so that the flow of electrical energy is unidirectional; from generation to consumers. This means that the components that form it, the protections that are installed and the operation of all systems are developed with this in mind. This system, which has worked well for more than a century, exhibits certain defects which have meant that this configuration is currently being reconsidered.

Without exploring them in depth, the main problem is environmental impact because of the heavy use of fossil sources in the generation of electrical energy. These fuels, when burned, emit greenhouse gases (Weisser 2007), especially in the case of coal.

TABLE 3. FOSSIL FUEL SPECIFIC EMISSIONS

	g CO_2eq/kWh
NUCLEAR	1.5-20
NATURAL GAS	360-575
FUEL OIL	700-800
COAL	800-1000
LIGNITE	1,100-1,700

Source: Weisser 2007

Polluting emissions from electricity generation depend on the combination of energy generation methods and the local weather, which can increase or decrease renewable generation, particularly in Spain. In 2018, polluting emissions were estimated to be 0.246 tonnes of CO2/MWh, a figure that tends to fall as the percentage of renewables in the energy mix increases.

In the case of France, emissions are very low due to the high percentage of nuclear generation, which has practically zero CO2 emissions. However, the problems in this case come from the need to treat the waste that the power stations produce and the inherent risk of nuclear generation.

According to Eurostat, in 2016, the energy sector of the European Union emitted approximately 6.25 tonnes of CO2 per inhabitant. Specifically, Spain gave off 5.1t CO2/inhabitant, France 4.7t CO2/inhabitant and Portugal 4.47t CO2/inhabitant, meaning that all three countries are below EU average.

Another problem is the heavy dependence on energy sources from abroad given that most fossil resources are bought from other countries. The following table shows the percentage of energy that is imported by each country in respect to the total primary energy in 2015.

TABLE 4. TOTAL ENERGY DEPENDENCE 2015				
Country	**Spain**	**France**	**Portugal**	**European Average**
Energy dependence	79.1 %	47.1 %	73.5 %	53.6 %
Source: Weisser 2007				

According to this, in 2015 Spain imported 96.9% solid fuels, petroleum derivatives and natural gas with France importing 98.7% and Portugal 99.8%. In terms of nuclear energy, despite Spain having its own uranium reserves, the cost of extraction means that it is currently acquired from abroad. In 2016, France also imported almost 100% of its uranium as it only produced 3tU of a total of 8000tU that was used (IAEA/NEA 2018).

This in itself creates two major problems. The first is that the cost of acquisition of fossil fuels leads to a significant deficit in the trade balance and the second is that the countries are vulnerable in situations of international conflict.

The third issue with the current EPS is that it is an inefficient system. The generation by thermal cycles is not at all efficient. For example, coal plants have levels of efficiency that can vary from 32% to 42% while gas power stations oscillate between 32% and 38% but combined cycle plants can work at 60% efficiency. Nuclear power stations have efficiency levels of between 33% and 37%, although the most modern plants can reach 45%. In general, the use made of fossil fuels is less than 50%.

Furthermore, the distance between the points of generation and consumption also leads to a high level of loss, both in the transport grid and the distribution grid. According to the International Energy Agency (IEA) in 2014, these losses were estimated to be at 9.5%, in France 6.4% and in Portugal 10%.

In general, the efficiency of the current electrical system in Spain is estimated to be at less than 40%. This strongly contrasts with renewable energies; whose efficiency is almost 100% in the generation phase.

Another problem with the current EPS is that it is difficult to plan. The design, construction and commissioning of a large power plan or transport line implies high costs and more importantly, long periods of amortization, all of which require good forecasting of possible demand.

Furthermore, they are costly to run. Although most generation centres which use fossil fuels have low or moderate installation costs (€/kW), the cost of fuel means that the cost over its life cycle is often very high and is in fact currently higher than the cost of the entire life cycle of renewable generation sources (Ernest & Young 2012) (IRENA 2018) as well as being subject to variations in price of fossil fuels.

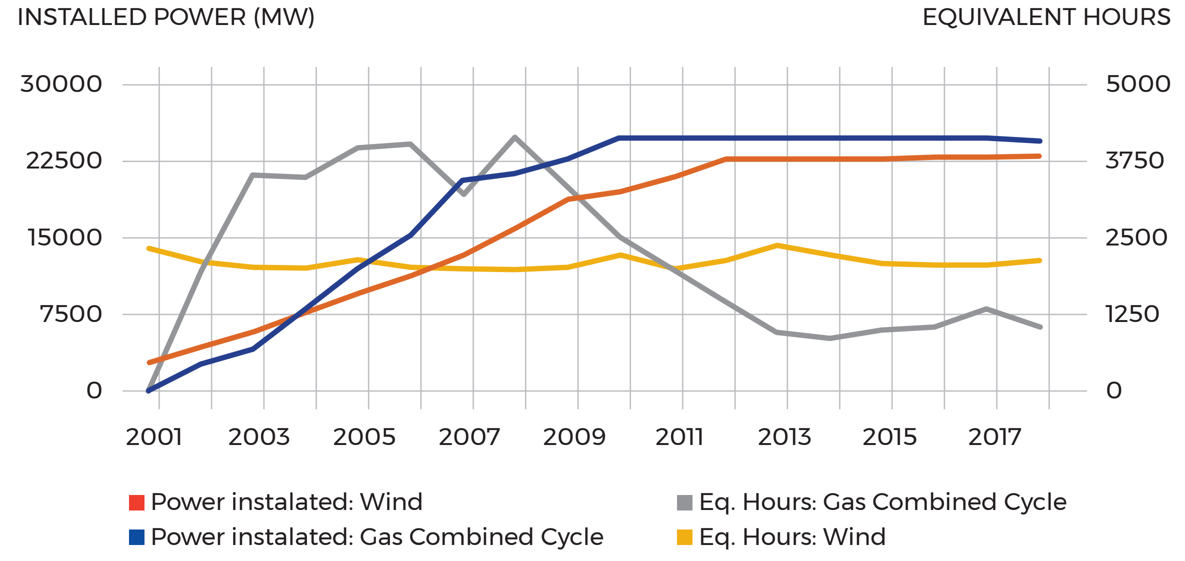
The monitoring and operation of a complex network also poses problems. To meet the variable demand under the adequate conditions of continuity and stability of supply, any stable and synchronous systems must ensure a practically constant state of functioning, with a very small range of variation

(50 Hz + 0,5 Hz) and virtually constant voltage within the established margins and with an adequate waveform. The way to control this is to make sure that the values of active and reactive power are always adequate. When these conditions are not met, ill-timed disconnections can occur, leading to power cuts and blackouts. These power cuts happen with some frequency in grids that are weak or saturated but they can also occur in large power grids and can then affect other countries, such was the case in a blackout that occurred in November 2006 in Germany (UCTE 2006) and that, due to the failure in the functioning of a high-voltage grid, affected more than 15 million users in Germany, France, Belgium, the Netherlands, Italy and Spain. In 2003, another blackout began in Italy (Berezzi 2004) due to a falling tree and affected 55 million people in Italy and Switzerland.

It is also difficult to integrate renewable energies into the EPS. The main sources of renewable energy that are currently being developed and installed are wind and photovoltaic generation. These generation sources are connected to the electricity network and modify the grid's habitual behaviour at the connection point (Trebolle et al. 2012). These generation sources do not add inertia to the system, which is the main way to guarantee the constant frequency in the grid. For this reason, most countries have chosen to introduce other sources which are capable of providing the necessary inertia in order to compensate for the loss in the grid. The following figure shows how in Spain, the increase in number of wind energy installations has been accompanied by an even greater increase in combined cycle generation (CCG), which does provide the grid with inertia.

However, it is necessary to point out that the number of equivalent hours of CCG decreased to a minimum of 846 hours in 2014, something that happened as photovoltaic generation increased. This indicates that it is not necessary to have that virtual inertia, at

FIGURE 2: POWER INSTALLED IN SPAIN AND EQUIVALENT HOURS OF WIND ENERGY AND CCG



Source: own elaboration from REE data

least not continuously. In addition, the low number of operation hours means that these installations incur losses.

Furthermore, it can be seen from the annual data published by (the Spanish TSO – (REE) that when compared with the year 2001, there has been an increase of 50% in the installation of non-renewable power, which the production with these generators has been reduced by 8%. On the other hand, the increase in renewable installed capacity is 150% and renewable production has increased by almost 104%. The average amount of power used in 2018 by a Spanish EPS is 27GW, and the maximum peak was 40.95GW.

All of these problems mean that it is essential to modify and modernize the EPS. One of the principal objectives of any modernization would be to increase the penetration of renewable energies in order to reach a scenario where 100% renewable energy use is the norm, bringing with it the advantages that this incurs: reducing energy dependence and amount of polluting emissions. Other objectives are to ensure the steady supply of energy and to reduce the costs of both infrastructure and operation. In order to do so, there have been discussions for some time now about several innovative concepts such as distributed generation, the smart grid and microgrids. These concepts will be briefly explained below.

THE NEW ELECTRICAL POWER SYSTEM

As discussed above, a fundamental transformation of the EPS is necessary. The first objective is to increase the penetration of Renewable Energies (RE). One of the major differences between fossil systems and REs is that the latter must be located where the resource is optimal. In the case of solar energy, it could be said that it can be used in almost any location. However, this is not the case for wind energy and hydraulics. On the other hand, the advantage of renewable energies is that installations can be realized from hundreds of watts to MW, and they can be installed in cities and towns: in homes, buildings, shopping centres and parks. They can be installed in industrial facilities or in large companies, that is to say near consumption points and therefore greatly reducing transport losses and reducing the cost of the corresponding infrastructure. This is the basic concept of distributed generation.

There is no single definition for the concept of distributed generation (Thomas et. al 2001), especially when it refers to the power of generation systems, the voltage at which they operate, the place where they connect and even the generation technology they use (IEEE Std 1457 TM; DOE 2003; EPRI 2003; IEA 2002; Directive 2003/54/EC of the European Parliament, EPA 2019).

However, it can be concluded that distributed generation is generally considered to be generated near consumption points, preferably of renewable original (although not solely) and operate at medium or low voltage, and that it also includes storage systems. The distributed generation and storage systems that together form the Distributed Energy Resources (DER) can work when connected to the distribution grid or in isolation.

There are many advantages that make distributed generation so interesting. Most importantly, the level of polluting emissions is significantly lower, as is energy dependency. It is quicker to build and has lower installation costs, meaning it is easier to plan investments and there is less financial risk. In terms of operation, it is more adaptable to demand and there is less possibility of technological or general failure. It can work connected to the grid, in which case it is cheaper to maintain and transport but it can also work in isolation. A final benefit is it creates high-skilled jobs at a local level and therefore improves the local economy.

However, in order to make distributed generation a reality, it is necessary to improve the exploitation of energy resources and the connection of renewable generation systems to the grid, either in an isolated or interconnected manner. It is also essential that the problem of the randomness of renewable sources be solved and that predicting generation and demand be improved. And it is evident that the transport and distribution grids need to be adapted.

As mentioned above, the electricity grid is not prepared for a massive roll-out of distributed energy, which is why it is necessary to adapt and modify the current electricity grid in terms of both transport and distribution. Here, there are two basic proposals (Blarke & Jenkins 2013): the Supergrid and the smart grid.

The basic surmise of the Supergrid is that it covers a supranational area and operates using high voltage and direct current (HVDC), into which other grids are integrated and which theoretically would be able to absorb all renewable generation without the need for storage systems or demand management techniques. In summary, it tries to reinforce the current centralized system through the development of technologies that allow for greater transport capacity.

On the other hand, the smart grid constitutes a complete change in the concept of the current grid in terms of both distribution and transport. Among the many definitions of what a smart grid is, one that stands out is that provided by the Smart Grid Dictionary (Hertzog 2010) that defines it as an 'electrical and bi-directional communication network which improves the reliability, safety and efficiency of the electrical system for the generation, transmission, distribution and storage of energy from a small to large scale'. Another definition by the EU Commission Task Force for smart grids defines a smart grid as 'an electrical grid that can integrate in a profitable way the behaviour and actions of all users that connect to it (generators, consumers and those who do both) to guarantee a sustainable energy system which is economically efficient with low levels of losses and high levels of quality, security of supply and security for people'.

Basically, a smart grid is using the latest available technology and developing others that are needed to be able to efficiently control and manage the millions of new generation and storage systems of any power that is expected to be connected to the grid in order for energy to flow in any direction safely, efficiently and the lowest possible cost. Among the new elements to consider, the electric vehicle

TABLE 5: MAIN CHARACTERISTICS OF A SMART GRID	
FLEXIBLE	- Be flexible and adaptable to the changing needs of the electric system - Be bi-directional: consumer-provider bi-directional flows
INTELLIGENT AND SAFE	- Be able to operate and protect itself securely and easily, be it for operational failures, natural disasters, and attacks on infrastructure or cyberattacks - Anticipate and respond to disruptions in the system, carrying out continual self-evaluations to detect, analyse, respond to and, if necessary, restore grid components or sections of grid - Ensure necessary information is available in real-time
EFFICIENT	- Uses assets in an intensive and safe way - Satisfies energy needs while minimizing need for new infrastructures
OPEN	- Integrates renewable energies and storage systems with plug & play connections in a safe way - Integrates the electric vehicle with the possibility of V2G - Allows for new business opportunities: new services, markets and products - Permits the active participation of the consumer and prosumer
SUSTAINABLE	- Respects the environment and is fundamentally based on renewable generation - Be socially accepted

Source: (Carbajo 2011)

has recently made its appearance as one more element of the smart grid.

The expected benefits of smart grids are many (Carbajo 2010, DOE/NETL-2010, NIST 2014, Asmus et al. 2012). First, they offer an improvement in terms of security and quality of the electricity grid supply: it will be a highly-sensorized, automated and connected system with real-time reporting ability. This will reduce the frequency and duration of supply interruptions and the likelihood of blackouts and fluctuations in energy quality. Any failures will be dealt with quickly thanks to the system's ability to detect the exact location of the fault and the automatic management of the grid. In the event that the grid does go down, the supply will be able to be maintained in an isolated way. It will respond to demand, predicting the demand at points of production and thus optimizing the use of renewable sources. It can also improve supply to saturated grids as well as weaker ones, allowing an increase or decrease in the power consumed including autochthonous generation and storage systems, as well as a better management of reactive energy. There will also be a smaller probability that the grid suffers a hacking attack. Furthermore, smart grids also offer a higher level of safety for employees because if interruptions to supply decrease, as do the number of interventions and therefore the subsequent risk to people.

Smart grids also offer economic benefits for the EPS. The increase in installations of renewable generation creates business opportunities in distributed generation and energy storage. They avoid over-dimensioning of infrastructures and an improvement in the efficiency when using facilities, working at optimum levels to reduce operation and maintenance costs. There are fewer losses due to transportation and when interruptions are reduced, the penalties decrease. Fewer interruptions also mean increased revenues for generators and lower maintenance costs because they operate in a more continuous way, making it easier to manage the 'health' of the system. This in turn increases the useful life of the system assets. Employee productivity is likely to increase due to information of a better quality and subsequently improving O&M processes. The appearance of new business models, products and services within the smart grid concept will likely lead to greater competitiveness and open new markets which generate income for other new concepts such as flexibility services; one likely source of income will be the sale of electric vehicles. Moreover, there is likely to be a reduction of non-technical losses and customer management and billing costs. A high level of interaction with the clients, including through mechanisms of active management of demand, is likely to allow a better forecast of the use of infrastructures.

For the consumer, smart grids offer higher levels of satisfaction due to improved service and a reduction in costs due to service interruptions which affect production processes, food conservation etc. and the use of the grid's own renewable sources. Consumers will have access to more information about energy prices so that consumers can make conscious decisions regarding their own consumption and therefore benefit economically. They will also be able to install their own generation and storage and there will be the possibility of selling excess energy, not only to the grid but also to third parties, namely the prosumer. Development conditions are set to improve, thus allowing the supply to reach more disadvantaged areas (be they rural, isolated or saturated). The consumers can expect to see an increase in the life of any equipment connected to the grid thanks to an improvement in wave quality. It will be easy to charge electric cars and even items with V2G functionality.

Smart grids offer immense benefits for society in general. Jobs linked to new technologies will be created, including in rural areas associated with renewable generation systems. There will be an improvement in the quality of life in areas with weak grids, allowing for greater opportunities for growth and the establishment of new businesses and subsequent improvement of trade balance due to a reduction in energy dependence. This in turn allows for greater ease in planning the purchase of fossil fuels (which will be reduced even more once electric vehicles are deployed) and anticipating price variations. It will be easier to plan long-term investments, reducing the risk of error and cost of the system, especially in the case of large generation plants and transport lines.

It is also expected that the population's health will improve due to a decrease in polluting emissions. But the benefits also extend to the environment as there will be a reduction in greenhouse emissions as the use of renewable energies increases and the rollout of VE is permitted.

Because of its importance in the change in concept for consumers, it is fitting to highlight a novel concept that brings smart grids and new business models together: the prosumer, a combination of producer and consumer. This is the new name that will be applied to those consumers who have their own generation facilities and can therefore produce energy, although this term can also extend to those capable of storing and even transporting energy (Muzzi et al. 2013).

All of the above certainly presents an idyllic panorama for the EPS and prosumer and although much is being done to ensure that this is achieved, there is still a lot of actions to take and much technology to be developed.

TECHNOLOGICAL DEVELOPMENTS NECESSARY FOR SMART GRIDS AND DISTRIBUTED GENERATION

Smart grids and distributed generation mean a transformation of the EPS that will allow for an essential improvement for the integration of renewable energies. Universities, research centres and companies have been working for years to make this possible and yet, there still remains much to do. It needs a great deal of research and development and as new technology advances, new challenges appear and new goals can be achieved but many of these are still unknown. The following section outlines the areas of current research.

New Materials

Work is underway on the development and commercialization of new materials that allow for the improvement of storage systems, the transport capacity of power lines or the performance of electric supply devices among others. In the specific case of the devices, it is interesting to compare wide band-gap devices based on Silicon Carbide (SiC), Gallium Nitride (GaN), Gallium Oxide

TABLE 6: MATERIAL AND ELECTRICAL PROPERTIES OF VARIOUS SEMICONDUCTORS

Material properties	Conventional	Wide band-gap semiconductors				
	Si	4H-SiC	GaN	Ga2O3	Diamond	2H-AlN
Bandgap Eg [eV]	1.12	3.26	3.39	5.5-4.9	5.45	6.2
Intrinsic concentration ni [cm-3]	1.5 x 1010	8.2X10-9	1.9x10-10	2.6x10-19	1.6x10-27	10x10-34
Dielectric constant Ɛr	11.8	10	9.9	10	5.5	8.5
Carrier mobility µn [cm2/Vs]	1350	720-650	1000-2000	300	2800	300
Breakdown field Ec [MV/cm]	0.25	2	3.3-3.75	8	10	12
Saturation drift velocity Vsat [107 cm/s]	1	2	2.5	-	2.7	1.2
Thermal conductivity [W/cm.K]	1.5	4.5	2.50-4.1	0.13-0.21	22	2.85
Maximal operation temperature Tmax [C˚]	125	500	650		700	

Source: (Chow et al. 2017) (Bakowsky 2000) and diamond and Silicon-based devices, the advantages of which can be seen in the following table.

Devices with wide band-gap can operate at a higher voltage and frequency than silicon-based devices, which reduces the size and volume of current devices as well as the noise they produce. In addition, they achieve efficiencies of between 95% and 99.5% (Armstrong et al. 2016) which the silicon-based devices only achieve 85% to 98%, reducing losses by up to 75%. Therefore, highly efficient wide band-gap devices are essential in increasing the efficiency of electric conversion systems.

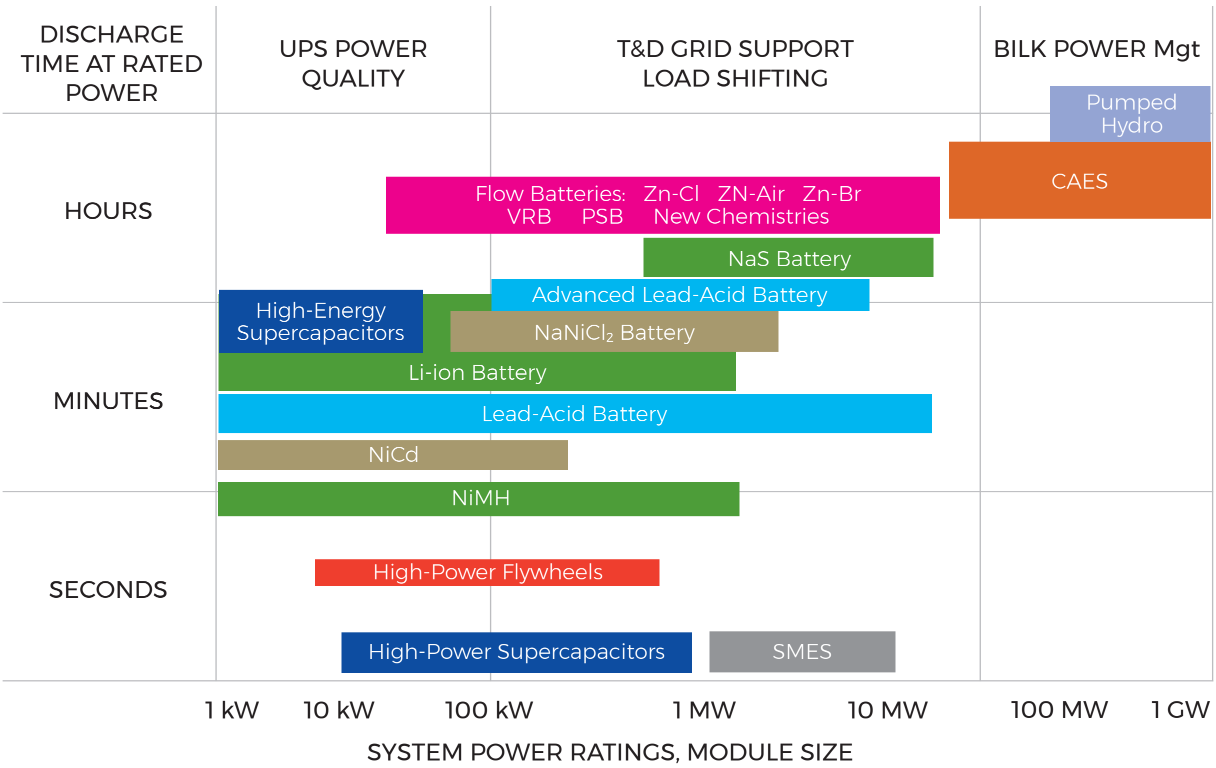
Storage

Storage is a key element for the introduction of DG and the smart grid since it allows generation to be independent from demand, allowing various applications at very different voltages (Mahora et al. 2016). Depending on the application and voltage, there are multiple technologies that may be more appropriate but there is not one single piece of technology that provides 100% optimal working conditions so this is still a matter under investigation.

One of the most important aspects in the research into batteries is discovering how to reduce the type and quantity of critical raw materials which are difficult to find or are only found in small amounts in Europe, such as vanadium, lithium and cobalt.

As for superconductivity, this is characterized by the absence of measurable resistance in certain conditions. Finding a material that guarantees the total lack of resistance and thus makes

FIGURE 3: POSITIONING OF ENERGY STORAGE TECHNOLOGIES



Source: DOE/EPRI 2016

TABLE 7: CURRENT PERFORMANCE OF PRINCIPAL BATTERY TECHNOLOGIES

Technol-ogy	Energy density Wh/kg (Wh/L)	Power density W/kg (W/L)	Life time (years)	Cycle life (cycles)	Current Cost			Roundtrip efficiency (%)
					$(€)/kW	$(€)/kWh	$(€)/kWh/ cycle	
PbO2	30-50	75-300	5-15	500-1000	200-300$	120-600$	3.072 €/kWh	65-90
NiCd	45-80	150-300	10-20	1000-2500	500-1500$	800-1500$		>90%
NiMH	60-120	100-300	10	<1000		500$		80%
NiFe	50		20					
NiZn	100	100-200	10-20	<300				70
NiH	40-75	220		>20000				85
Li-ion	75-241 (200-535)	500-2000	5-15	500-2000	1200-4000$	500-1000€	25c€/kWh/ cycle	85-90
NaS	150-240 (150-250)	150-230	10-15	2500	1000-3000$	300-500$	8-20$	70-90
NaNiCl	100-120 (150-180)	150-200 (220-300)	10-14	2500+	150-300$	100-200$	5-10$	85-90
VRFB	10-30 (15-25)		5-20	>10000	600-1500$	150-1000$	5-80$	85-90
ZnBr	30-60 (30-60)	100	5-10	>2000	700-2500$	150-1000$	5-80$	70-80
HBr				10000	0.25€/W	80€/kWh	0.05€	
ZnAir	150-3000 (500-10000)	200 W/l			100-250$	10-60$		50-55

Source: (Anke et al. 2016) (SusChem 2017) (Durant et al. 2017) (Becker et al. 2017) (Gallo et al. 2016) (Rohit et al. 2017) (Chen et al. 2009) (Díaz 2012) (Pawel 2014)

losses via conduction negligible would mean great advantages in terms of transport and distribution of electrical energy, transformers and machines (Doukas 2019). As an example, research is currently being carried out on HTS (High Temperature Semiconductors high temperature superconductor cables for both AC and DC transmission, which would allow 5 to 10 times the current density of the conduction equivalent of copper. Another very promising application is the energy storage by means of a magnetic field (SMES), which is created by the circulation of a direct current round a superconducting ring cooled to a temperature below the critical temperature of superconductivity. The efficiency of such systems reaches 95% and even though it has a high power density, its energy density is low so it is possible for these systems to compete with supercapacitors and inertia flywheels in the same field of application. The biggest drawback of these systems is that they need to work at temperatures ranging from 80K to 4K, depending on whether liquid nitrogen, gaseous helium or liquid hydrogen is used.

Advanced Technologies

A fundamental aspect is the need for integration of renewable energies and storage systems (Rehmani et. al 2018). The variability and randomness of RE, especially wind and to a lesser extent photovoltaic, means that to supply a certain level of demand, a combination of both is essential. Similarly, for a 100% renewable future, both energies need to be complemented with others such as hydraulics or biomass. When discussing integration, it is not a matter of simply joining different sources but instead it refers to how they can be connected and controlled together and therefore guarantee the stability of the electrical grid to which they are connected and the security of consumer supply. However, a 100% renewable future is impossible if various storage systems that allow some level of independence between generation and demand are not developed and installed. These compensate for the variability in renewable energies and provide ancillary services for grid stability.

In this way, energy storage must cover various time scales and functions:

- From milliseconds to a few minutes, they need to solve sudden power variations in generation or consumption which can affect the stability of the system by modifying its voltage and/or frequency, using mainly supercapacitors, SMES or inertia flywheels.
- From minutes to hours, they need to also provide virtual inertia to the grid for a longer period of time in order to help keep voltage and frequency values within limits. They also guarantee the continuity of supply, deal with the variability of renewable energies and of the hourly loads, demand curve flattening, isolated operation in case of grid failure, etc. For these, electrochemical batteries, fuel cells and thermoelectric storage are used.
- From hours to days, they need to guarantee a continuous supply which, in addition to the above, allows for isolated operation for longer period and with greater loads, delay investments in new infrastructures or allow time for installation of more renewable generation etc. In this case, this is usually by means of hydraulic pumping or storage systems with compressed air in caverns (CAES).

In any case, the optimal solution is a combination of storage systems together with renewable systems with an integrated control that always guarantees the quality and security of supply.

The configuration of Power Electronics is necessary for renewable generation systems such as wind, solar, variable-speed hydraulic, to be connected to the grid. In addition to storage systems, either electrochemical, electrostatic or SMES, there are dozens of types of loads: electric vehicles, elevators and lighting systems, for example.

For this, multiple configurations according to need are used, with AC/DC, DC/AC and DC/DC converters, which can be unidirectional or bidirectional. The DC/DC converters may or may not include galvanic isolation by means of an intermediate transformation in AC and a medium frequency transformer (generally of several kHz).

These electronics must ensure the optimal operation of the system to be controlled as well as the production of a high-quality wave on the grid side. And this is always with the highest level of efficiency possible. The quality of the wave becomes even more crucial as the number of these systems connected to the grid increases. In this sense, it must be ensured that not only is the harmonic content low but also that the reactive energy is always close to zero, regardless of the power range in which it operates.

It is important to point out that power electronics can perform important auxiliary functions for the grid. For example, a converter can continuously monitor the frequency value and the voltage at the connection point and manage the delivery and active and reactive power according to demand. Similarly, it can monitor the waveform and perform filtering functions and improve said waveform. Therefore, any system connected to the grid through a power electronic stage could perform some of the functions that a STATCOM and/or harmonic filtering do. In order for this to happen, research is being carried out on new configurations, such as multi-level bridges, with new devices, such as those with Silicon Carbide, and more efficient switching techniques.

Electronics are playing an important role in improving the quality and security of supply of transport grids through systems called FACTS (Flexible AC Transmission System), which allow controlling parameters that govern the operation of the transmission systems (Glanzmann 2005), including the series impedance, derivation impedance, current, voltage, phase angle and oscillation damping.

The main functions of FACTS (Peng 2017) in an intelligent grid are: a) increase renewable energy penetration; b) improve power transfer capacity; c) prevent undesired power flows; d) achieve a rapid and dynamic voltage regulation and frequency control; e) power share between lines in parallel to avoid overload or sub-loads; and f) improve margins of existing grid stability.

Another area of study is the so-called Solid State Transformer (SST). This is a piece of equipment based on power electronics that replaces the traditional transformer (She & Huang 2013) and that boasts a wide range of advantages, including the possibility of including some of the functionality of FACTS, better performance when dealing with distorted or unbalanced loads, better compensation of the potency factor, included protection in topology, allowance for powering loads with DC offset, prevention of fault propagation in the grid, possibility of being designed with direct current outputs for integration of storage systems from the beginning etc. Its main drawback is the high cost, something that is likely to decrease as Silicon Carbide (SiC)-based devices go down in price.

Electric Vehicles (EV)

Electric Vehicles (EVs), whether they are pure electric (BEVs) or plug-in hybrids (PHEVs), are another important component of the smart grid. EVs present an unbeatable opportunity to reduce greenhouse gases and the trade balance deficit seeing as Spain, France and Portugal import nearly 100% of their oil. However, EVs need a very specific infrastructure to be able to charge them. There are several charging modes (IEC 61851, CHAdeMO) from slow charging at 3.7kW to 50kW fast charge. TESLA has 250kW charging capabilities while the super-fast 350kW charge (Porche) is currently still being developed. It is expected that buses will need charging at an even higher potency (ZeEUS 2019).

In order to have a clearer idea of what this means for the grid, it is perhaps preferable to take a simpler approach. An EV for private use consumes about 0.14 kWh/km so for an average daily journey of 40km, it requires 5.7kWh/day, which is 2100 kWh/year for 15,000 km. This is higher than the average travelled by European citizens (EEA 2016). It is expected that the EVs would be charged daily at home using a slow charge of 3.7kW. This consumption is approximately equivalent to the consumption of a typical dwelling in Spain that is occupied by two people. It hardly seems like an enormous amount of energy.

But what if there is a massive rollout of electric vehicles? And that the inhabitants of a building containing 72 dwellings all wanted to use electric vehicles? Taking an average degree of electrification (5.75Kw/dwelling) and applying the corresponding simultaneity coefficients, the building's connection would be approximately 245 kW. Assuming all vehicles are charged using a slow charge, the power required for the 72 vehicles would be 270kW, which is more than the building consumes itself. By extrapolating these numbers, it is clear that the demand at a city level would be doubled, causing an increase in the number of transformation centres and wiring to reach charging points. This would create a real problem at the level of the infrastructure, firstly due to the cost incurred and then because it would be impossible to carry out said work in neighbourhoods of densely populated cities where there is no space for new transformation centres, not to mention the inconvenience that such works may cause.

Continuing with a hypothetical situation, if 100% of the vehicles in Spain were electric (that is to say all types of vehicles), there would be more than 32 million vehicles. While maintaining the previous hypothesis of charging power and travel need, which admittedly is a very simplistic approach considering the variety of vehicles and uses but it allows a quick approximation of the problem, the result for total power required for the simultaneous charging of these vehicles would be 118.4 GW, which is higher than all of the installed power in the peninsula as of December 2018 (98.7GW). If energy consumption is analysed, it will reach 67.2GWh/year, an increase of electricity demand of 26.5% in 2018.

The numbers above show that the rollout of electric vehicles is not a simple matter of changing vehicles but rather they imply significant modification and adaptation of electric transport and distribution grids at a very high cost. In addition, more in the distribution grid, other problems will appear that will likely affect both the quality and safety of the electrical supply, starting with voltage drops that can be caused by fast charges or harmonic distortions that will produce dozens of chargers connected to the same point.

However, the advantages of the electric vehicle, both in terms of environmental impact and economical balance due to the need to import 100% of the oil used, are unquestionable.

Does this therefore mean that we have reached a dead end? Far from it. All it means is that electric cars need to be thought of as being something more than just a simple car. It will form a fundamental part of the electric grid and will have to be treated as such.

From the point of view of the grid, the electric vehicle is a battery with wheels that connects to the electric grid more than 95% of the time in many cases. It is very predictable in terms of behaviour and it is obvious where it is and where it will be for the next few hours and it is possible to know what charge the batteries carry and what energy a driver will need to have for the next journey. For this reason, this battery can be used in a way that allows for optimal management of energy flows without saturating the grid and even helping to ensure the quality and security of supply.

An orderly rollout implies various things.

- The need to manage charging according to grid conditions, especially in private and public buildings where the vehicle charging power has to be regulated in real time based on other energy consumption.
- The rollout of fast chargers that eliminate anxiety caused by batteries running out and allow for batteries to be recharged quickly while limiting the impact this has on the grid, which limits the possibility of installation and increases expenses due to the increase in power used. To solve this problem, it is necessary to develop solutions that include charging management in real-time, integration with storage systems and with renewable energies and more efficient power electronics with less harmonic and silent content.
- The development of charging technologies that are easier to use and which the user is hardly taxed and does not need to use cables. This suggests that charging by induction would be most interesting, both at low power levels for end users as well as at high power levels which would allow opportunity charging and even dynamic charging.
- The improvement of the interaction between the user, the infrastructure and the grid operator, allowing for the user to be given information in a simple, easy and transparent way about the costs of charging, available offers etc.
- The vehicle's battery can be used as a grid support (Zhoy & Li 2015) by adding energy into it, helping stabilize (V2G) or by providing isolated charges (V2L) and even helping charge other vehicles (V2V).

Electric vehicles present us with an opportunity to not only reduce polluting gases and energy dependence but also represent a commodity that will allow research into new storage methods, thus improving their performance and reducing their cost. In addition, once the battery is unable to reach 80% of its nominal capacity during charges, it will be removed and used as grid support or for use in homes (referred to as the battery's second life). This gives it an important residual value and therefore reduces the cost of the EV.

FINAL REMARKS

It is obvious that the basis of a fundamental change and an essential part of the smart grid is new software technologies and advanced communications. The operation of the smart grid is based on the possibility of bi-directionally communication with the millions of devices and sensors that are connected, and in many cases sending operation commands. Therefore, it is essential to develop protocols and computer programs that guarantee this communication and management in real time wherever possible.

Of all the services that Information and Communication Technologies (ICT) must provide, the most important are perhaps the automatization of the Medium Voltage grid, control and operation of the distribution grid, the Smart Metering infrastructure, the detection of technical and non-technical losses, electric vehicle charge management and support for Demand Management.

In order for this to be achieved, the principal characteristics that ICT technologies and protocols must have are that they are flexible in order to be able to integrate future services, technologies and protocols; scalable so that it is possible to connect with millions of points (in the grid and end consumers); Plug&Play in order for new connections to work automatically and be recognized by the control centre and the immediate environment; High Availability to monitor and meet the quality required by services; technologically independent with several suppliers for each solution; and finally secure with the possibility to include information security mechanisms and improve the systems' physical security and thus avoiding cyber-attacks with the aim of data theft or which compromise the security of the service.

An interesting concept, because it is already installed through Europe, is the new Advanced Metering Infrastructure (AMI). This measuring configuration is composed of a set of elements including Smart Meters, communicated with a Data Concentrator Units (DCUs), which sends aggregated data to a Head End System (HES). HES is a software that receives the data from the smart meters and sends the DSO commands to the Smart Meters. The data are processed with the Meter Data Management System (MDMS) and later used for some utility applications like billing, customer care, etc. Communication is then bidirectional and uses Wide Area Network (WAN), Neighbourhood Area Network (NAN)/Field Area Network (FAN) and Home Area Network (HAN) (Ahuja A. et al. 2017).

With this, it is possible, among other things, to reduce costs and errors in the measurement of energy consumption, to detect non-technical losses, quickly find out the consumption and allow for a better estimate of the demand curve, promptly connect and restore service to customers after a failure, find out the quality of the supply grid, detect overloaded areas in the distribution grid and allow hourly rates.

In light of the above points, it is evident that it will be necessary to manage tens of thousands of systems, or perhaps even millions, which implies an enormous level of complexity. One way to simplify the task is to group together consumers and generators into microgrid. A microgrid consists of a group of chargers, generators and storage systems that function as a single, controllable system that supplies electrical energy to a determined zone (Kumar, A. et al. 2018). They can work either connected to a grid, in isolation or both.

The interconnection of systems in the microgrid can be done synchronously in alternating current or asynchronously in direct current (Bryan 2004). The latter implies that it is only necessary to control voltage and current in the DC bus and therefore without reactive power, the need to control frequency or synchronise equipment. This makes control much simpler and makes the grid more stable. In addition, it reduces the number of power electronic configurations and increases efficiency. The biggest disadvantage is that, because the grid is currently synchronous, there are not many loads prepared for this type of integration.

The microgrid will normally have a controller, which will communicate with each and every one of the connected elements and the different sensors that are necessary, and receive information from them and generate output in real time. The purpose of the microgrid controller may vary depending on user preferences. It may be to reduce electricity bills, maximize renewable generation or minimize energy consumed by the general grid, for example. However, the power supply for consumers must always take preference. To ensure this happens, it will send instructions to the generation and storage systems, and even disconnect loads at times.

The grouping of systems in microgrids allows the grid management system to reduce the number of components that need to be controlled, since there is only one interlocutor (the microgrid controller) instead of repeated elements.

There are many other technological developments in progress that aim to improve mini and micro sources of generation: photovoltaic (NREL 2019) (Sing et al. 2018), miniwind (Bukala et al. 2016) (Kishore et al. 2013), wave energy (Faiad et al. 2018) to name a few. Also, in micro-cogeneration and micro-trigeneration systems (Al Moussawi et al. 2016), the function is to take advantage of the residual heat of a thermal engine to produce hot water (DWH) and heating (also air-conditioning in trigeneration systems) while electricity is produced. For these aspects, research is being done on steam turbines, micro gas turbines, internal combustion micro engines and Sirling engines (Ahmadi et al. 2017). Similarly, there are important developments surrounding the use of hydrogen and its generation (Dincer 2012) (Hosseini & Wahid 2016) and storage (DOE 2017) as well as in fuel cells (E4tech 2018).

However, given space limitations, it is not possible to discuss these and many other topics, all of which indicate a very promising future, with substantial technical challenges that will undoubtedly lead to an EPS that is much more efficient, sustainable and non-polluting and one in which we, the consumers, play a key role.

REFERENCES:

AEMA 2016 “Señales de la AEMA 2016” https://www.eea.europa.eu/es/senales/senales-2016/articulos/el-transporte-en-europa-datos

Ahmadi M, Ahmadi M, Pourfayaz F, “Thermal models for analysis of performance of Stirling engine: A review”, Renewable and Sustainable Energy Reviews, Volume 68, Part 1,2017, Pages 168-184.

Ahuja A. et al. “Smart grid Handbook for Regulators and Policy Makers”. Indian smart grid Forum/ Shakti Sustainable Energy Foundation. 2017

Al Moussawi H., Fardoun F., Louahlia-Gualous H. “Review of tri-generation technologies: Design evaluation, optimization, decision-making, and selection approach”. Energy Conversion and Management. Elsevier 15 July 2016

Aneke M. and Wang M. (2016), Energy storage technologies and real life applications – A state of the art review, Applied Energy, 179, 350-377.

Armstrong K.., Das S., and Cresko J., “Wide bandgap semiconductor opportunities in power electronics”, 2016 IEEE 4th Workshop on Wide Bandgap Power Devices and Applications (WiPDA)

Asmus, P, Lockhart B, Stroher N, Bae A, Gohn B. “Smart grid: Ten Trends to Watch in 2012 and Beyond”. Pike Research LLC 2012

Bakowski, M. “Roadmap for SiC Power Devices,” Journal of Telecommunications and Information Technology,vol.3.4,pp19-30 2000

Banco Mundial (2019) Transmisión de energía eléctrica y pérdidas en la distribución (% de producción)

Becker B.; Gil Bardají M. E.; Durant J-M., Clerens P., Noe M. (2017) “European Energy Storage Technology Development Roadmap” Joint EASE/EERA 2017.

Berizzi, A. (2004). “The Italian 2003 blackout”. 1673 - 1679 Vol.2. 10.1109/PES.2004.1373159.

Blarke MB, Jenkins BM. Super grid or smart grid: Competing strategies for large-scale integration of intermittent renewables? Energy Policy 2013;58:381–90. http://dx.doi.org/ 10.1016/ j.enpol.2013.03.039

Bryan J., Duke R. and Round S., “Decentralized generator scheduling in a nanogrid using DC bus signaling,” IEEE Power Engineering Society General Meeting, 2004., Denver, CO, 2004, pp. 977-982 Vol.1.

Bukała J., Damaziak K., Kroszczyński K., Malachowski J., Szafrański T., & Tomaszewski M.& R. Karimi H., Jozwik K., Karczewski M., & Sobczak K., (2016). “Small Wind Turbines: Specification, Design, and Economic Evaluation”. 10.5772/62821.

Carbajo. “Las redes eléctricas inteligentes: Seguridad, estabilidad y sostenibilidad del sistema” (2011). Obtenido de : https://slideplayer.es/slide/1056690/

CHAdeMO: https://www.chademo.com/

Chen H., Cong T.N., Yang W., Tan C., Li Y., Ding Y. “Progress in electrical energy storage system: a critical review.” Progress in Natural Science Volume 19, Issue 3, 10 March 2009, Pages 291-31210 March 2009, Pages 291-312

Chow T. P., Omura I., Higashiwaki M., Kawarada H., and Pala V., “Smart power devices and ICs using GaAs and wide and extreme bandgap semiconductors,” IEEE Trans. Electron Devices, vol. 64, no. 3, pp. 856–873, 2017.

Comillas (2019) https://www.comillas.edu/Documentos/BP/sankey_energy.html

Díaz-González, F., et al. (2012) “A review of energy storage technologies for wind power applications’, Renew. and Sust. Energy Rev., vol. 16, no. 4, pp. 2154–2171

Dincer I. “Green methods for hydrogen production”. Int J Hydrogen Energy, 37 (2012), pp. 1954-1971

Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC

DOE (April, 2017) “Hydrogen storage” https://energy.gov/eere/fuelcells/hydrogen-storage

DOE/EPRI (2016) Electricity Storage Handbook in Collaboration with NRECA

(https://www.google.com/search?q=positioning+of+energy+storage+technologies+2017&rlz=1C1TEUA_esES837ES837&tbm=isch&source=iu&ictx=1&fir=LGJ--G-BoZudgM%253A%252C2L2M44OJ7445WM%252C_&vet=1&usg=AI4_-kRoxPnCjgAHOIAUJQKXsXazspWQsg&sa=X&ved=2ahUKEwiCxpuwjariAhUSQBoKHd_3Cn8Q9QEwAHoECAkQBA#imgrc=LGJ--G-BoZudgM:&vet=1)

DOE/NETL-2010/1413 "Understanding the Benefits of the smart grid Implementation Strategy" June 18, 2010

Doukas D. .I "Superconducting Transmission Systems: Review, Classification, and Technology Readiness Assessment" IEEE Transactions on Applied Superconductivity, vol. 29, no. 5, august 2019

Durant J.M., Duarte M. and Clerens P., "Recommendations for a European Energy Storage Technology Development Roadmap Towards 2030". Joint EASE/EERA

E4tech 2018 "The Fuel Cell Industry Re DOE. http://www.fuelcellindustryreview.com/

ENTSO-E ELECTRICITY IN EUROPE 2017. Synthetic overview of electric system consumption, generation and exchanges in 34 European countries

ENTSO-E Inventory of generation

EPA United States Environmental Protection Agency https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts 2019

Ernest & Young 2012 "Analysis of the value creation potential of wind energy policies. A comparative study of the macroeconomic benefits of wind and CCGT power generation". https://www.edpr.com/sites/default/files/portal.edpr/documents/ey_acciona-edp_value-creation-of-wind-policies-summary-02081211.pdf

EU Commission Task Force for smart grids. Expert Group 1: Functionalities of smart grids and smart meters (2010)

European Academies Science Advisory Council.. Valuing dedicated storage in electricity grids. EASAC policy report 33 (May 2017).

European Commission. "EU energy in figures. Statistical pocketbook 2018" ISSN 2363-247X

EUROSTAT (2016) Energy dependence (source: EEA)

EUROSTAT (2016) Greenhouse gas emissions by sector (source: EEA)

Faiad A. A. and Gowaid I. A., "Linear generator technologies for wave energy conversion applications: A review," 2018 53rd International Universities Power Engineering Conference (UPEC), Glasgow, 2018, pp. 1-6.

Gallo, A.B., et al., Energy storage in the energy transition context: A technology review. Renewable and Sustainable Energy Reviews, 2016, 65 (Supplement C): p. 800-822.

Glanzmann, G. (2005). FACTS: flexible alternating current transmission systems.

Hertzog, C., 2010. Smart grid Dictionary, second ed.

Hosseini S., Wahid M. "Hydrogen production from renewable and sustainable energy resources: promising green energy carrier for clean development" Renew Sustain Energy Rev, 57 (2016), pp. 850-866

IAEA/NEA (2018) Nuclear Energy Agency and International Atomic Energy Agency 2018 "Uranium Resources, Production and Demand" http://www.oecd-nea.org/ndd/pubs/2018/7413-uranium-2018.pdf

IEC 61851:2017 Electric vehicle conductive charging system

IEEE Application Guide for IEEE Std 1547™, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

International Energy Agency (IEA). Distributed Generation in Liberalized Electricity Markets. OECD/IEA, Paris, France, 2002.

IRENA 2018: "Renewable Energy Statistics 2018": https://www.irena.org/publications/2018/Jul/Renewable-Energy-Statistics-2018

Kishore R., Coudron T., Priya S.J., (2013). "Small-scale wind energy portable turbine (SWEPT)". Journal of Wind Engineering and Industrial Aerodynamics. 116. 21–31. 10.1016/j.jweia.2013.01.010.

Kumar, A., M Akbar Hussain. D, Zafar Ullah Khan,M. . (2018). Microgrids Technology: A Review Paper. Gyancity Journal of Electronics and Computer Science. 3. 11-20. 10.21058/gjecs.2018.31002.

Malhotra A., et al. (2016), Use cases for stationary battery technologies: A review of the literature and existing" projects, RSER, 56, 705-721.

Muzi F., De Lorenzo M. G. and De Gasperis G., "Intelligence Improvement of a "Prosumer" Node through the Predictive Concept," 2012 Sixth UKSim/AMSS European Symposium on Computer Modeling and Simulation, Valetta, 2012, pp. 311-316.

NIST Special Publication 1108r3 "NIST Framework and Roadmap for smart grid Interoperability Standards, Release 3." http://dx.doi.org/10.6028/NIST.SP.1108r3

NREL 2019 : https://www.nrel.gov/pv/cell-efficiency.html

Pawel . I; (2014)."The Cost of Storage – How to Calculate the Levelized Cost of Stored Energy (LCOE) and Applications to Renewable Energy Generation (€/kWh/cycle)" Energy Procedia Volume 46, 2014, Pages 68-77

Peng, F. Z "Flexible AC Transmission Systems (FACTS) and Resilient AC Distribution Systems (RACDS) in smart grid", Proceedings of the IEEE, vol. 105, no. 11, pp. 2099-2115, 2017.

Porche: https://www.teslarati.com/porsche-taycan-charging-time-2x-faster-tesla-superchargers/

Raj Singh U., Kumar A., "Review on solar Stirling engine: Development and performance". Thermal Science and Engineering Progress. Volume 8, 2018, Pages 244-256,

RED Electrica de España (2019) "emisiones de CO2 asociadas a la generación anual nacional"

Rehmani M. H., Reisslein, M., Rachedi A., Erol-Kantarci and Radenkovic M., "Integrating Renewable Energy Resources Into the smart grid: Recent Developments in Information and Communication Technologies," in IEEE Transactions on Industrial Informatics, vol. 14, no. 7, pp. 2814-2825, July 2018.

Rohit, A.K., et al., An overview of energy storage and its importance in Indian renewable energy sector: Journal of Energy Storage, 2017. 13(Supplement C): p. 10-23.

She X. and Huang A., "Solid state transformer in the future smart electrical system," 2013 IEEE Power & Energy Society General Meeting, Vancouver, BC, 2013, pp. 1-5.

SUSCHEM, Battery Energy Storage, White paper, European Technology Platform for Sustainable Chemistry, SusChem Materials Working Group 2018.

TESLA:https://www.theverge.com/2019/3/6/18253618/tesla-supercharger-250kw-v3-specs-location

The Electric Power Research Institute, online publications available at: http://www.epri.com/, 2002.

The US Department of Energy, Office of Distributed Energy Resources, online publications available at: https://www.energy.gov/eere/slsc/renewable-energy-distributed-generation-policies-and-programs

Thomas, A. Göran, S. Lennart "Distributed generation: a definition". Electric Power Syst. Res., 57 (3) (2001), pp. 195-204

Trebolle, David & Frías, Pablo & María Maza, José & Luis Martínez, José. (2012). El control de tensión en redes de distribución con generación distribuida (I). Anales de mecánica y electricidad. Marzo-Abril.

Trebolle, David & Frías, Pablo & Maza-Ortega, J.M. & Tello Guijarro, Jorge. (2012). El control de tensión en redes de distribución con generación Distribuida (II). Anales de mecánica y electricidad. Mayo-Junio.

UCTE 2006 "Final Report - System Disturbance on 4 November 2006". https://www.entsoe.eu/fileadmin/user_upload/_library/publications/ce/otherreports/Final-Report-20070130.pdf

VVA, Copenhagen Economics, Neon, Deloitte. "Study on the quality of electricity market data of transmission system operators, electricity supply disruptions, and their impact on the European electricity markets" Final report. European Commision

Weisser, (2007) "A guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies" Energy, 32 (2007), pp. 1543-1559

ZeEUS: https://zeeus.eu/

Zhou Y. and Li X., "Vehicle to grid technology: A review," 2015 34th Chinese Control Conference (CCC), Hangzhou, 2015, pp. 9031-9036.

INNOVATION IN THE NEW ECONOMY. REQUIREMENTS FOR A HEALTHY INNOVATION SYSTEM

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THE ROLE OF INNOVATION IN THE NEW KNOWLEDGE SOCIETY

"Future is not what it was", as claimed by a well-known sentence, apparently of graffiti authorship. And it is not, because the impressive technological advances that we have seen in the last years are changing, at an exponential pace, the foundations of our life as individuals and as social community, including the way we eat, we move, we keep healthy, we reproduce and age, we learn and teach, we work, we make business or we communicate and interact. These changes are shaping so strong structural transformations in the educational, labor, socio-economic, political and human relations that many philosophers identify this time with a point of discontinuity in our civilization that will change the roots of our species [1] [5].

The breakage of these long-standing social bases is leading to societies politically fragile and with a high level of uncertainty at practically all levels: employment, security, cultural stability, etc., with the well-known reactions of fear and defense of the own identity. But, at the same time, these societies are socially and culturally richer and much more adaptable. The specialists have coined different terms to describe this new society: informational, technological or knowledge are some of the adjectives that qualify it.

The latter is probably the most adequate. Knowledge is the most genuine human production, constituting, not only the necessary substrate to preserve the identity of a community, but it is also the only way for increasing global wealth with fixed resources, thus raising the global standard of living, and allowing to reduce inequalities and promote social change.

Some of the most relevant socio-economic characteristics of this knowledge society are:

- The exponential evolution of technological changes, the universal dissemination of information and the world coverage of communications.
- The growing dependence of the wealth of a community on the creation and dissemination of knowledge

as well as its exploitation into high added value assets via the recursive cycle of training, research and innovation.
- The global integration of economy and the increasing value of diversity and transdisciplinarity.
- The demand for new skills and abilities closer to the capacity to innovate than to the traditional manual work, which implies the need for permanent adaptation and continuous learning.

A critical factor for any community is therefore its capacity to access, produce, store, analyze and exploit the enormous amount of data and information available, and to transform it into knowledge via training, transmission of experience or exploitation of the new capacities of big data and artificial intelligence to, finally, converting that knowledge into economic and social value through innovation. Promoting this virtuous cycle should be therefore one of the first responsibilities of any public administration.

INNOVATION IN THE NEW ECONOMY. PLAYERS AND ROLES

Derived from the facts mentioned above, we are experimenting the emergence of new organizational forms of production and commercialization, expression of an economic model that cannot be understood only from the interaction between the traditional factors of production (capital, land, labor), but otherwise, it is consequence of the capacity to generate, accumulate, use and disseminate knowledge and technology.

The time between scientific discovery and its widespread use is getting shorter and shorter with the associated fast technological obsolescence. There are studies that predict that 40% of the products and services that exist today will disappear in five years and 50% of those who by then will supply the market are not yet known. Also, some of the technologies with higher impact in the next decade did not exist just 10 years ago [6].

The numbers leave no room for doubt. The World Bank has calculated that the 29 countries that account for 80% of the total wealth of the planet owe 67% of their welfare to intellectual capital (education, scientific and technological research, systems of information), 17% to natural capital (raw materials) and 16% to productive capital (machinery, infrastructures). This growing “dematerialization” of the economy implies that the standard of living of our societies depends more and more on the efficiency in training, the quality of the research and innovation system, the capacity for creation and access to information and, in turn on the intellectual capital.

As a result, new economic spaces are created, while, at the same time, others that become non-competitive disappear, modifying the relative importance of each economic sector, as happened in the industrial revolution. Also, we attend to a progressive displacement of the competition based until now on the scale of production, the reduction of cost and the product quality towards a new one based on the differentiation and fast substitution of products, what some authors have called the change “from scale to scope” [4].

Globalization, dematerialization, desectorialization, differentiation, continuous change and adaptation are the keywords that define the new economy. This is driving to a gradual but inexorable redefinition of the international division of labor, which represents a great opportunity for countries without natural resources and poor industrial development, but with high-quality human resources. This is also producing strong tensions in the job market, with structural unemployment in traditional activities, compatible with a tremendous unmet demand for specialists in activities associated with the new economy. Jobs that did not exist just five years ago are now among the most demanded [7].

But it is not only the employment, but the same concept of work that is structurally changing. Since the industrial revolution, companies demand hours to work in a place from their employees. Today, location and synchronization are no longer necessary to carry out a job, just as the presence of buyer and seller is not necessary in the same place and at the same time, to carry out an e-commerce operation. It is not so important what has to be done and less how it has to be done, but what are the goals to achieve, such as quality, price or time to market. The imagination and creativity of the provider (more than the worker) will determine how, when and where to do it.

Furthermore, manual, repetitive and protocoled jobs are being automatized at a fast rate that is expected to grow even faster in the next years, in favor of more imaginative and innovative tasks more difficult to be protocoled. This process demands new skills such as creativity, learning and adaptation capacity, personal autonomy, critical thinking, potential for producing knowledge and innovation, human and business relationships, ability for team-work and for communication in several languages, cultural diversity and technological competence.

With respect to companies and institutions, the new environment in which they develop their activity (globalization, speed of change, complexity, technological pressure) also implies higher demands in terms of flexibility, change management, culture of learning, specialization, networking and, finally, in considering knowledge and intangible assets as strategic value. Knowledge-based companies encourage continuous training of their human resources, rewarding people for their ideas, outsource many of their tasks and promote stable and strategic agreements with universities and scientific centers. Although this model implies a greater degree of dependency and uncertainty, it also increases flexibility and adaptability, reduces risk and increases complementarity. An example is the so-called “cluster-matrix model”, conformed of conglomerates of collaborating or even competitive companies that share information with the purpose of competing globally more efficiently. It is particularly noteworthy the growing appearance of companies engaged in gathering data and information, in developing scientific-technical analyses, contract research organizations, data banks and a long list of similar institutions that conform an emerging and high added value sector that “manufactures” and sells “knowledge”.

Universities and research centers are also progressively aware of this major change. They have not only lost the monopoly of training (e.g. on-line courses, talks and MOOCs, goal-oriented training and research centers), but they are also losing their preeminent role as knowledge producers. The traditional knowledge creation model based on recognized research institutions or research departments in companies (model M1 according to Gibbons et al. [2]) is being progressively complemented (or substituted) by a new model (M2 in the nomenclature of Gibbons et al. [2]) more blurred, where the new discoveries appear in the development of an application (applied research and innovation) and not in the search of knowledge "per se" (basic research). This scenario competes advantageously in the highly complex challenges that our society faces, such as the climate change, aging and demography, global wealth redistribution, water and energy scarcity, jobs automatization, etc., to name just a few. It is in the context of these large-scale applications with great organizational and technological complexity, in which groups of very different institutions cooperate, where the knowledge that will mark our future is coming out.

Finally, the role of the administration is essential in establishing an adequate environment for innovation. Public administration has fundamental responsibilities in the education and training of the population at the highest possible level, in promoting basic research and long-term support of innovation, in strengthening the connection between innovation, research and business, in building research infrastructures and in knowledge dissemination to name only a few. The many research framework programs of the European Union, the different national research plans or the regional research, development and innovation (RDI) programs are sufficient proofs of the need to establish general guidelines, prioritize topics and application sectors, identify and support long-term scientific trends and enhance the efficiency of the innovation system as a whole.

From all above, it is clear that setting an efficient innovation system is not easy and requires the concourse of many actors, both national and foreign, public and private, academic and productive, but, on the other hand, it is a necessary condition to increasing wealth and equality.

HOW TO DEFINE AND HOW TO MEASURE INNOVATION? THE GLOBAL INNOVATION INDEX

There are many definitions for innovation, but one of the most used is the following: "Innovation is any action or process that turns knowledge into wealth or social value, generating valuable resources from organizational and individual talent.". In contraposition, pure research produces new knowledge through scientific or heuristic methods, but without the specific aim of creating value. Of course, the line separating both is very thin and most times research and innovation work together, especially in the mentioned M2 model.

Although from the previous definition, it is clear that innovation can be found at any place and time, it is usually grouped into three broad categories:

- Revolutionary, disruptive or discontinuous innovation that gives rise to a completely new technology or process that changes completely one or several markets and/or social activities. Examples can be 3D printing, internet, advanced genomics, or solar technologies to name a few.
- Incremental, continuous or evolutionary innovation that is brought about by incremental advances in a preexisting technology. For example, the extension of 3D printers from original polymer-based materials to metals or ceramics, the continuous improvements of mobile phones and in transmission protocols (1G to 5G), new fast gene sequencing techniques or the incredible evolution of silicon-based photovoltaics.
- Translational innovation refers to the transfer and assimilation of one technology into a new application or industrial sector. The use of 3D bioprinters in regenerative medicine, using smart phones for health monitoring, adaptation of the CRISP-R technique to treat gene diseases or using solar cells for domestic appliances are examples of this kind.

Regarding the field of application, although we find again innovations in any economic activity and all along the production and organizational process, we usually distinguish between:
- Product innovation, which involves the introduction of a new good or service or the improvement of a preexisting one. This might include improvements in functional characteristics, technical abilities, easiness of use, or any other product feature.
- Process innovation that involves the implementation of a new or significantly improved production or delivery method.
- Market innovation that corresponds to the development of new marketing methods with improvements in design, packaging, product promotion or pricing.
- Organizational innovation (also referred to as social innovation) which involves the creation of new organizations, best business practices, ways of running organizations or new organizational behavior.
- Business model innovation that is associated with changes in the way the whole business is done. For example, substitution of retail shop-based selling to on-line distribution.

As commented in the introduction, innovation has demonstrated to be the most important factor along history for reducing inequalities, while keeping human progress, being difficult to overestimate its importance in the improvement of human quality of life. There are multiple indicators that show a direct relationship between the innovative capacity of a country and its potential for growth, or, more specifically, between the investment effort in research and innovation and the economic competitiveness in the long term. It is not strange therefore that countries and regions try to foster the innovation in their companies and institutions, as well as to improve their whole innovation system by:
- Strengthen the different innovation agents and their interactions
- Accompanying or supporting other actors of the innovation ecosystem (e.g. venture and seed capital)
- Providing resources (people, infrastructures, ...)

- Supporting side policies like education and dissemination, taxes, talent attraction, etc.

But how to measure this innovation effort and its results? The best compilation of indicators related to innovation for each country and the derived performance is provided since 2007 by The Global Innovation Index (GII) [3]. This report includes an annual ranking of countries by their capacity for, and success in, innovation. It is published by the Cornell University, INSEAD and the World Intellectual Property Organization, in partnership with other organizations and institutions.

The GII is based on both subjective and objective data derived from several sources and is computed by taking a simple average of the scores in two major indexes related to input and output, respectively. The first is composed of five sub-indexes or pillars, namely: institutions, human capital and research, infrastructures, market sophistication and business sophistication, while the second is formed by two subindexes: knowledge and technology output and creative output. Each of these pillars describe an attribute of innovation, and comprise several indicators as shown in the corresponding summaries for France, Portugal and Spain in the GII 2018 report, included in the Appendix [3].

REQUIREMENTS FOR A HEALTHY INNOVATION SYSTEM

Looking at the GII main pillars, it is not difficult to identify the aspects that define a healthy innovation system and therefore have to be object of special care to be promoted and controlled.

Regarding the administration and the socio-economic environment, we can cite:

1. A good educational system at all levels with a correct matching of scientific training and social and labor skills with companies' needs
2. A high social recognition of research, science and scientists
3. The existence of a clear and agreed long-term RDI strategy and a high priority of RDI policies in every administration. An objective could be to arrive to figures in the order of 3% of GDP in the whole country R&D investment, with a correct distribution (about 40-60) between public and private agents
4. A correct coordination with European policies and between national regions to avoid repetitions and promoting complementarity, differentiation and specialization
5. A flexible management system that allows changes of objectives, budget application or contracts
6. Facilities for creating new companies with non-burocratic and clear rules and strong and flexible financing and tax policies
7. Promotion of emergent technologies through the regulations, tax policy or public contracts that can be used as innovation attractors
8. Policies for talent attraction and retention in a wild international competition with sufficient recognition, incentives and continuity
9. Reduce barriers to mobility of RDI personnel between public and business sectors; and
10. Promotion of regional ecosystems with companies, universities, technological centers and other institutions.

Regarding companies:

1. RDI has to be considered an essential component of the company success. As consequence, the BERD and RDI employment have to be sufficient (e.g. the effort in RDI of Spanish companies is half of the European average)
2. A correct and strong innovation and IP protection strategy
3. A professional and flexible management of RDI projects
4. Varied and sufficiently flexible financing instruments for technology-based companies
5. A reasonable and balanced size of the different companies (e.g. a high percentage of very small companies reduces chances for investment and organization of their RDI policies)
6. Increase and promote businesses involved systematically in RDI
7. High level of companies' digitalization, particularly in SMEs
8. Increase, with a correct HHRR policy, the workers profile (number of researchers, of graduates in STEM, and of workers in knowledge intensive services...)
9. An efficient knowledge management and a fast technology-absorption capacity.

Regarding the knowledge creation and technology transfer system:

1. A strong strategy for technology transfer with sufficient involvement of companies
2. A flexible governance and management of the innovation projects in universities and research centers
3. Structures and policies oriented both to research output but also to technology production and transfer, with an appropriate policy of recognition/incentives
4. A correct internal innovation strategy;
5. A differentiation and specialization strategy in terms of own strengths and capacities in RDI
6. An appropriate policy for talent attraction and retention, both for students and staff
7. A strong policy for IP protection, spin-off creation and know-how commercialization
8. Sufficient and well-trained professionals involved in technology transfer (IP, commercialization, search of opportunities...)
9. An RDI policy based, not only on short term projects and consulting, but also in strategic collaborations and/or long-term big projects
10. Policies and tools to leverage co-investment in high-risk projects but with much higher and recurrent pay-back.

STRENGTHS AND WEAKNESSES OF THE INNOVATION SYSTEMS OF FRANCE, PORTUGAL AND SPAIN

Figure 1, extracted from the GII 2018 report, shows the first 50 countries in the global ranking, where we can see that France, Portugal and Spain occupy the positions 16, 28 and 32 respectively, being the two latter below countries such as Estonia, Malta or Czech Republic. Although France performs better, its position is below all other western and northern European countries, except Belgium, and other international players, well-known for their strong innovation systems, such as USA, Japan, Switzerland, or South Korea and even others, much smaller but intensive in innovation, like Israel, Singapore or Hong-Kong. All this means that, despite the differences, traditions and policies, all of them are performing in innovation

FIGURE 1. FIRST 50 COUNTRIES IN THE RANKING OF THE GLOBAL INNOVATION INDEX 2018

Country/Economy	Score (0–100)	Rank	Income	Rank	Region	Rank	Efficiency Ratio	Rank	Median: 0.61
Switzerland	68.40	1	HI	1	EUR	1	0.96	1	
Netherlands	63.32	2	HI	2	EUR	2	0.91	4	
Sweden	63.08	3	HI	3	EUR	3	0.82	10	
United Kingdom	60.13	4	HI	4	EUR	4	0.77	21	
Singapore	59.83	5	HI	5	SEAO	1	0.61	63	
United States of America	59.81	6	HI	6	NAC	1	0.76	22	
Finland	59.63	7	HI	7	EUR	5	0.76	24	
Denmark	58.39	8	HI	8	EUR	6	0.73	29	
Germany	58.03	9	HI	9	EUR	7	0.83	9	
Ireland	57.19	10	HI	10	EUR	8	0.81	13	
Israel	56.79	11	HI	11	NAWA	1	0.81	14	
Korea, Republic of	56.63	12	HI	12	SEAO	2	0.79	20	
Japan	54.95	13	HI	13	SEAO	3	0.68	44	
Hong Kong (China)	54.62	14	HI	14	SEAO	4	0.64	54	
Luxembourg	54.53	15	HI	15	EUR	9	0.94	2	
France	54.36	16	HI	16	EUR	10	0.72	32	
China	53.06	17	UM	1	SEAO	5	0.92	3	
Canada	52.98	18	HI	17	NAC	2	0.61	61	
Norway	52.63	19	HI	18	EUR	11	0.64	52	
Australia	51.98	20	HI	19	SEAO	6	0.58	76	
Austria	51.32	21	HI	20	EUR	12	0.64	53	
New Zealand	51.29	22	HI	21	SEAO	7	0.62	59	
Iceland	51.24	23	HI	22	EUR	13	0.76	23	
Estonia	50.51	24	HI	23	EUR	14	0.82	12	
Belgium	50.50	25	HI	24	EUR	15	0.70	38	
Malta	50.29	26	HI	25	EUR	16	0.84	7	
Czech Republic	48.75	27	HI	26	EUR	17	0.80	17	
Spain	48.68	28	HI	27	EUR	18	0.70	36	
Cyprus	47.83	29	HI	28	NAWA	2	0.79	18	
Slovenia	46.87	30	HI	29	EUR	19	0.74	27	
Italy	46.32	31	HI	30	EUR	20	0.70	35	
Portugal	45.71	32	HI	31	EUR	21	0.71	34	
Hungary	44.94	33	HI	32	EUR	22	0.84	8	
Latvia	43.18	34	HI	33	EUR	23	0.69	39	
Malaysia	43.16	35	UM	2	SEAO	8	0.66	48	
Slovakia	42.88	36	HI	34	EUR	24	0.74	28	
Bulgaria	42.65	37	UM	3	EUR	25	0.79	19	
United Arab Emirates	42.58	38	HI	35	NAWA	3	0.50	95	
Poland	41.67	39	HI	36	EUR	26	0.69	42	
Lithuania	41.19	40	HI	37	EUR	27	0.63	58	
Croatia	40.73	41	UM	4	EUR	28	0.70	37	
Greece	38.93	42	HI	38	EUR	29	0.59	74	
Ukraine	38.52	43	LM	1	EUR	30	0.90	5	
Thailand	38.00	44	UM	5	SEAO	9	0.71	33	
Viet Nam	37.94	45	LM	2	SEAO	10	0.80	16	
Russian Federation	37.90	46	UM	6	EUR	31	0.58	77	
Chile	37.79	47	HI	39	LCN	1	0.60	68	
Moldova, Republic of	37.63	48	LM	3	EUR	32	0.89	6	
Romania	37.59	49	UM	7	EUR	33	0.66	47	
Turkey	37.42	50	UM	8	NAWA	4	0.75	25	

Source: taken from [5]

well below their respective capacity in terms of GDP and scientific strength. What are the reason for this? What is failing in our innovation systems?

Looking now at the scores and ranking of each of these three countries in the different dimensions analyzed, it is possible to detect some weaknesses that drive, at the end of the day, to reductions and imperfections in the corresponding performance in innovation and that strongly impact in productivity, salaries, unemployment or import-export balance. In some of them, Spain and Portugal perform especially bad.

We can identify as main weaknesses in France those corresponding to Institutions and Knowledge and Technology Outputs and more in particular, the political, regulatory and business environments. We have also to remark the poor marks in knowledge creation and impact. This demonstrates a stiff environment for creation of new businesses, and an insufficient translation from basic to applied knowledge and valuable products and businesses, something typical of most European countries. With respect to Portugal and Spain, similar comments can be made, with lower absolute numbers but with relative better performance, especially in Spain regarding knowledge creation, while additional weaknesses can be identified. For example, business sophistication in Spain and business and market sophistication in Portugal. This shows that they have, not only a stiff administrative environment like in France, but also a social culture and a business structure that do not help in promoting new businesses intensive in research, difficulties in hiring highly educated people and a global economy with a high weight of low added value sectors like tourism. Finally, a particular need in Portugal is associated to the insufficient infrastructures in ICT and research, essential for a fast development of knowledge-intensive activities.

A careful look at the GII-2018 shows also some common strengths of the three innovation systems such as:

1. Good RDI capacities in Universities, PROs, and R&D centers
2. A reasonable number of researchers and RDI personnel with critical mass of scientists and technicians in some areas
3. A high quality and international impact of the scientific production, especially in certain areas
4. Advanced scientific and technological infrastructures
5. Social appreciation of science
6. Scientific, technological and business leadership in some strategic areas depending on the country (biotechnology, energy, ICT, etc.)
7. Important and advanced communications infrastructures, except in Portugal
8. High percentage of population with tertiary education
9. Intensive use of ICTs in government and population, although not so intensive in Portugal and in Spanish companies; and, finally
10. Good environmental indicators.

What should be done, in any case, to change the unfavorable situation in our countries and, with that, change the economic model (especially in Portugal and Spain) like other countries such as South Korea, Finland, Israel or Estonia did in last years? The next section includes several proposals, some of them easy to establish and others that require cultural changes and long-term investment in education and values, but, in any case, unavoidable to maintain the quality of life and keep social peace while, at the same time, support equal opportunity, taking care of the most disadvantaged and reduce inequalities.

PROPOSALS FOR IMPROVEMENT

Once a diagnosis has been made, we are ready to present and discuss some of the proposals to improve a national innovation system. Any strategy in this direction requires, as a first and compulsory premise, a global political and social long-term agreement of the whole country to change the model of education, as well as the socio-economic values and priorities. These latter should turn towards the promotion of knowledge production, protection and attraction of individual and organizational talent, environment sustainability and permanent innovation as the main drivers of a healthy and strong growth model. Some of the proposals to achieve this, although with different importance and intensity for each country (France, Portugal and Spain in our case), are the following:

Social environment:

1. A pedagogical effort is essential to gain social recognition of the value of education, continuous learning, effort and risk
2. A change in the social vision of the role and value of Science, Art, Technology and Culture is mandatory
3. Major changes in education at all levels are required, including bigger resources, more innovative methods, programs for the formation of educators in the new knowledge society and adaptation of the curricula, promoting STEM areas, languages, cultural diversity, multidisciplinarity, transversality and the use of new technologies
4. A global and interiorized policy of social cohesion and exclusion of the marginality with integration projects for the elderly, rural population, immigrants and the disabled, linked to the recognition of cultural, linguistic and capacity diversity
5. Sufficient RDI infrastructures, institutions of excellence and ecosystems
6. Talent creation, attraction and retention at all levels of education should be a state priority
7. Coordination and specialization of regions, universities and companies is essential in this incredibly competitive world
8. Promotion of the knowledge society by supporting the implementation of ICTs, the increase in the number of knowledge workers, the promotion of patents and collaboration with research and development agents

Administration:

1. An intense and stable policy of incentives and investments at all levels of the RDI system is required, prioritizing technology and innovation creation, transfer and assimilation
2. Implementation of a virtual administration program, extending the on-line services and including direct democracy pilot plans in different areas of administration
3. Special digitalization plans in key sectors such as health, justice, education or natural and historical heritage
4. Promotion of public access to all sources of information, strengthening public services in the network, free access to the Internet and digital education
5. Flexible rules in this changing world is a must, modifying the current burocratic paradigm to a new one based on fulfilment of objectives
6. Remove barriers and promote emergent technologies and start-ups with a favorable regulation, tax policy, public venture capital, grants with shared risk, etc.

Companies:

1. Size matters in companies (incentives for moving from SE to ME are required and not the contrary as usually happens)
2. Promotion of strategic networks and consortia in an appropriate RDI ecosystem that should include universities, centers of excellence, technology centers
3. An adequate innovation strategy is a must for any company, independently of its size and possibilities. It is a more a question of culture than money, so, if you cannot make research or innovation directly, do it openly or "wikily" and, if possible, in a strategic manner, within a consortium or cluster
4. Use the talent in your organization for rapidly assimilation and integration of new technologies and innovations
5. A company is worth its list of clients and its know-how, so they have to be especially protected and promoted.

Research and training agents:

1. Talent attraction both for students and researchers from everywhere should be the main goal of any world-class research center
2. An adequate innovation strategy for the institution itself is required
3. Universities must promote permanent and strategic collaborations within bigger consortia in big long-term projects
4. Professional structures are essential for proper technology transfer and innovation strategies (commercialize RDI results, define a well-designed IP protection policy and a proper strategy for spin-off creation favoring long-term payback)
5. Long-term investment, sharing risks along the aims of a well-defined strategic plan is key in the new economy
6. Continuous evaluation of the performance of the institution and its employees and their alignment with the strategy is the only way to advance.

CONCLUSIONS

The exponential growth of knowledge, technology, information and communication is changing our way of living such that we can foresee a disruption in our civilization. In fact, scientific and technological advances with the resulting innovative products and processes seem unstoppable. Also, innovation has demonstrated to be the most important factor for reducing inequalities, while keeping human progress.

Globalization, dematerialization, differentiation and permanent change and adaptation are some of the features that characterize the economy in the knowledge society. This implies fundamental changes in the job market, with structural unemployment in traditional activities, compatible with a tremendous unmet demand in activities associated with the new economy. This represents a great challenge, but also an opportunity for countries, regions and companies that have understood the need for skills such as technological competence, communication in different languages, creativity, learning and change adaptation, ability to produce knowledge and innovation, or cultural diversity.

The access, production, storage, analysis and exploitation of information, as well as its transformation into new knowledge and, finally, into economic and social value through innovation, are critical factors in the new economy. Promoting these factors is therefore one of the first responsibilities of any public administration. As a result, countries and regions have to improve the efficiency of their innovation systems, maintain a permanent adaptation and education of their human resources and foster innovation in their companies and institutions.

In average, France, Portugal and Spain, and all their actors, although with different intensity, do not perform as well as they should in innovation. It is true that they have some important strengths, highlighted in the previous sections, but focusing only in the weaknesses, we can mention in France a stiff environment for creation of new businesses and an insufficient translation from basic knowledge to valuable products and businesses, while, in Portugal and Spain, we have to add to that, an insufficient social prioritization of research and innovation, an economic structure with high weight of low-added value sectors like tourism, and an inefficient education system that does not match with industry needs. All these aspects hinder the appearance of new businesses intensive in research.

To conclude, a paramount change is required in our innovation systems to succeed in the challenges of this new world. We need a global agreement to change the model of education, talent and effort recognition as well as in the socio-economic priorities in our countries, bringing all social actors closer to the new values, skills and needs of the Knowledge Society. People talent and commitment as well as efficient organizational structures, flexible rules, a favorable environment for new businesses intensive in research and innovation are the essential ingredients to face the increasing world competitiveness. Only those countries with the determination to maintain the effort in RDI and adaptation will increase their quality of life in the long term, while keeping social peace and equality.

APPENDIX 1. MARKS OF FRANCE IN THE DIFFERENT INDEXES AND PILLARS OF THE GLOBAL INNOVATION INDEX 2018

FRANCE

GII 2018 rank

16

Output rank	Input rank	Income	Region	Efficiency ratio	Population (mn)	GDP, PPP$	GDP per capita, PPP$	GII 2017 rank
16	16	High	EUR	32	65.0	2,826.5	43,760.8	15

		Score/Value	Rank	
	Institutions	**81.2**	**21**	
1.1	Political environment	74.4	30	
1.1.1	Political stability & safety*	63.2	69	○ ◇
1.1.2	Government effectiveness*	80.1	20	
1.2	Regulatory environment	85.6	20	
1.2.1	Regulatory quality*	71.5	28	◇
1.2.2	Rule of law*	82.5	19	
1.2.3	Cost of redundancy dismissal, salary weeks	11.8	39	
1.3	Business environment	83.6	22	
1.3.1	Ease of starting a business*	93.3	22	
1.3.2	Ease of resolving insolvency*	73.9	26	

		Score/Value	Rank	
	Human capital & research	**56.8**	**11**	●
2.1	Education	57.2	29	
2.1.1	Expenditure on education, % GDP	5.5	32	
2.1.2	Government funding/pupil, secondary, % GDP/cap	26.9	19	
2.1.3	School life expectancy, years ⓓ	16.4	23	
2.1.4	PISA scales in reading, maths & science	495.7	24	
2.1.5	Pupil-teacher ratio, secondary ⓓ	12.9	53	○
2.2	Tertiary education	47.9	21	
2.2.1	Tertiary enrolment, % gross ⓓ	65.3	31	
2.2.2	Graduates in science & engineering, % ⓓ	25.3	30	
2.2.3	Tertiary inbound mobility, % ⓓ	9.9	20	
2.3	Research & development (R&D)	65.4	13	
2.3.1	Researchers, FTE/mn pop. ⓓ	4,307.2	21	
2.3.2	Gross expenditure on R&D, % GDP	2.2	12	
2.3.3	Global R&D companies, top 3, mn US$	86.3	8	●
2.3.4	QS university ranking, average score top 3*	70.5	12	

		Score/Value	Rank	
	Infrastructure	**62.9**	**10**	●
3.1	Information & communication technologies (ICTs)	87.4	7	●
3.1.1	ICT access*	86.4	11	●
3.1.2	ICT use*	79.3	16	
3.1.3	Government's online service*	94.2	5	●
3.1.4	E-participation*	89.8	12	
3.2	General infrastructure	51.4	26	
3.2.1	Electricity output, kWh/cap	8,243.6	19	
3.2.2	Logistics performance*	85.0	16	
3.2.3	Gross capital formation, % GDP	23.3	58	○
3.3	Ecological sustainability	49.9	27	
3.3.1	GDP/unit of energy use	10.3	46	
3.3.2	Environmental performance*	84.0	2	● ◆
3.3.3	ISO 14001 environmental certificates/bn PPP$ GDP	2.4	43	

		Score/Value	Rank	
	Market sophistication	**65.0**	**11**	●
4.1	Credit	45.7	37	
4.1.1	Ease of getting credit*	50.0	79	○
4.1.2	Domestic credit to private sector, % GDP	97.6	28	
4.1.3	Microfinance gross loans, % GDP	n/a	n/a	
4.2	Investment	67.4	9	●
4.2.1	Ease of protecting minority investors*	66.7	32	
4.2.2	Market capitalization, % GDP	82.2	19	
4.2.3	Venture capital deals/bn PPP$ GDP	0.3	1	● ◆
4.3	Trade, competition, & market scale	81.9	5	●
4.3.1	Applied tariff rate, weighted mean, %	1.6	19	
4.3.2	Intensity of local competition†	79.9	11	●
4.3.3	Domestic market scale, bn PPP$	2,826.5	10	●

		Score/Value	Rank	
	Business sophistication	**50.6**	**19**	
5.1	Knowledge workers	65.7	14	
5.1.1	Knowledge-intensive employment, %	45.2	13	
5.1.2	Firms offering formal training, % firms	n/a	n/a	
5.1.3	GERD performed by business, % GDP	1.4	14	
5.1.4	GERD financed by business, %	54.0	17	
5.1.5	Females employed w/advanced degrees, %	21.3	19	
5.2	Innovation linkages	38.9	39	
5.2.1	University/industry research collaboration†	53.7	34	◇
5.2.2	State of cluster development†	61.4	20	
5.2.3	GERD financed by abroad, %	7.6	49	○
5.2.4	JV–strategic alliance deals/bn PPP$ GDP	0.0	39	◇
5.2.5	Patent families 2+ offices/bn PPP$ GDP	3.3	13	
5.3	Knowledge absorption	47.0	17	
5.3.1	Intellectual property payments, % total trade	1.8	15	
5.3.2	High-tech net imports, % total trade	11.5	25	
5.3.3	ICT services imports, % total trade	2.3	18	
5.3.4	FDI net inflows, % GDP	1.1	101	○
5.3.5	Research talent, % in business enterprise ⓓ	59.7	11	

		Score/Value	Rank	
	Knowledge & technology outputs	**41.6**	**19**	
6.1	Knowledge creation	36.5	24	
6.1.1	Patents by origin/bn PPP$ GDP	9.0	15	
6.1.2	PCT patents by origin/bn PPP$ GDP	2.8	14	
6.1.3	Utility models by origin/bn PPP$ GDP	0.1	59	○ ◇
6.1.4	Scientific & technical articles/bn PPP$ GDP	17.6	31	
6.1.5	Citable documents H index	79.1	4	● ◆
6.2	Knowledge impact	43.7	32	
6.2.1	Growth rate of PPP$ GDP/worker, %	0.5	64	○
6.2.2	New businesses/th pop. 15–64	1.8	52	○
6.2.3	Computer software spending, % GDP	0.7	10	●
6.2.4	ISO 9001 quality certificates/bn PPP$ GDP	8.6	41	
6.2.5	High- & medium-high-tech manufactures, %	0.4	25	
6.3	Knowledge diffusion	44.5	14	
6.3.1	Intellectual property receipts, % total trade	2.1	10	●
6.3.2	High-tech net exports, % total trade	14.3	10	●
6.3.3	ICT services exports, % total trade	2.2	49	
6.3.4	FDI net outflows, % GDP	2.1	28	◇

		Score/Value	Rank	
	Creative outputs	**49.2**	**12**	
7.1	Intangible assets	62.2	7	●
7.1.1	Trademarks by origin/bn PPP$ GDP	103.6	11	◆
7.1.2	Industrial designs by origin/bn PPP$ GDP	7.4	17	
7.1.3	ICTs & business model creation†	78.3	13	
7.1.4	ICTs & organizational model creation†	71.0	19	
7.2	Creative goods & services	36.7	24	
7.2.1	Cultural & creative services exports, % total trade ⓓ	1.1	11	
7.2.2	National feature films/mn pop. 15–69	6.8	25	
7.2.3	Entertainment & Media market/th pop. 15–69	52.4	16	
7.2.4	Printing & other media, % manufacturing	1.1	54	○
7.2.5	Creative goods exports, % total trade	1.8	30	
7.3	Online creativity	35.9	24	
7.3.1	Generic top-level domains (TLDs)/th pop. 15–69	40.8	18	
7.3.2	Country-code TLDs/th pop. 15–69	20.4	28	
7.3.3	Wikipedia edits/mn pop. 15–69	64.7	15	
7.3.4	Mobile app creation/bn PPP$ GDP	38.9	18	

NOTES: ● indicates a strength; ○ a weakness; ◆ a strength **relative to the other top 25–ranked GII economies;** ◇ a weakness **relative to the other top 25;** * an index; † a survey question. ⓓ indicates that the country's data are older than the base year; see Appendix II for details, including the year of the data, at http://globalinnovationindex.org. Square brackets indicate that the data minimum coverage (DMC) requirements were not met at the sub-pillar or pillar level; see page 215 of this appendix for details.

Source: taken from [5] with permission

APPENDIX 2. MARKS OF PORTUGAL IN THE DIFFERENT INDEXES AND PILLARS OF THE GLOBAL INNOVATION INDEX 2018

PORTUGAL

GII 2018 rank

32

Output rank	Input rank	Income	Region	Efficiency ratio	Population (mn)	GDP, PPP$	GDP per capita, PPP$	GII 2017 rank
33	32	High	EUR	34	10.3	311.3	30,416.5	31

		Score/Value	Rank	
	Institutions	**81.2**	**23**	
1.1	Political environment	79.7	19	
1.1.1	Political stability & safety*	88.2	13	●
1.1.2	Government effectiveness*	75.5	24	
1.2	Regulatory environment	78.3	31	
1.2.1	Regulatory quality*	65.7	37	
1.2.2	Rule of law*	74.9	24	
1.2.3	Cost of redundancy dismissal, salary weeks	17.0	65	○
1.3	Business environment	85.5	18	●
1.3.1	Ease of starting a business*	91.3	41	
1.3.2	Ease of resolving insolvency*	79.7	14	●
	Human capital & research	**47.1**	**27**	
2.1	Education	58.2	25	
2.1.1	Expenditure on education, % GDP	5.1	47	
2.1.2	Government funding/pupil, secondary, % GDP/cap	29.3	13	● ◆
2.1.3	School life expectancy, years	16.3	27	
2.1.4	PISA scales in reading, maths & science	497.0	22	
2.1.5	Pupil-teacher ratio, secondary◷	9.9	28	
2.2	Tertiary education	45.0	28	
2.2.1	Tertiary enrolment, % gross	62.9	36	
2.2.2	Graduates in science & engineering, %◷	27.9	18	
2.2.3	Tertiary inbound mobility, %◷	5.0	38	
2.3	Research & development (R&D)	38.0	29	
2.3.1	Researchers, FTE/mn pop.	3,928.6	23	
2.3.2	Gross expenditure on R&D, % GDP	1.3	28	
2.3.3	Global R&D companies, top 3, mn US$	39.0	39	
2.3.4	QS university ranking, average score top 3*	36.0	35	
	Infrastructure	**53.0**	**37**	
3.1	Information & communication technologies (ICTs)	70.3	38	
3.1.1	ICT access*	79.1	28	
3.1.2	ICT use*	61.5	45	◇
3.1.3	Government's online service*	74.6	33	
3.1.4	E-participation*	66.1	49	
3.2	General infrastructure	35.9	72	○ ◇
3.2.1	Electricity output, kWh/cap	5,478.3	36	
3.2.2	Logistics performance*	62.3	35	
3.2.3	Gross capital formation, % GDP	16.5	109	○ ◇
3.3	Ecological sustainability	52.9	16	●
3.3.1	GDP/unit of energy use	13.0	21	
3.3.2	Environmental performance*	71.9	25	
3.3.3	ISO 14001 environmental certificates/bn PPP$ GDP	4.9	21	
	Market sophistication	**50.3**	**47**	
4.1	Credit	46.5	34	
4.1.1	Ease of getting credit*	45.0	88	○
4.1.2	Domestic credit to private sector, % GDP	112.0	21	
4.1.3	Microfinance gross loans, % GDP	n/a	n/a	
4.2	Investment	35.8	89	○ ◇
4.2.1	Ease of protecting minority investors*	60.0	56	
4.2.2	Market capitalization, % GDP	27.7	51	○
4.2.3	Venture capital deals/bn PPP$ GDP	0.0	35	
4.3	Trade, competition, & market scale	68.5	38	
4.3.1	Applied tariff rate, weighted mean, %	1.6	19	
4.3.2	Intensity of local competition†	70.9	56	
4.3.3	Domestic market scale, bn PPP$	311.3	51	

		Score/Value	Rank	
	Business sophistication	**36.5**	**43**	
5.1	Knowledge workers	48.4	37	
5.1.1	Knowledge-intensive employment, %	36.3	34	
5.1.2	Firms offering formal training, % firms	n/a	n/a	
5.1.3	GERD performed by business, % GDP	0.6	33	
5.1.4	GERD financed by business, %	42.7	35	
5.1.5	Females employed w/advanced degrees, %	15.9	40	
5.2	Innovation linkages	29.0	64	
5.2.1	University/industry research collaboration†	53.2	35	
5.2.2	State of cluster development†	53.1	38	
5.2.3	GERD financed by abroad, %	7.4	51	○
5.2.4	JV–strategic alliance deals/bn PPP$ GDP	0.0	68	○
5.2.5	Patent families 2+ offices/bn PPP$ GDP	0.5	33	
5.3	Knowledge absorption	32.0	55	
5.3.1	Intellectual property payments, % total trade	1.0	35	
5.3.2	High-tech net imports, % total trade	7.5	71	○
5.3.3	ICT services imports, % total trade	1.5	41	
5.3.4	FDI net inflows, % GDP	3.8	39	
5.3.5	Research talent, % in business enterprise	30.7	39	
	Knowledge & technology outputs	**32.2**	**36**	
6.1	Knowledge creation	24.3	40	
6.1.1	Patents by origin/bn PPP$ GDP	2.9	34	
6.1.2	PCT patents by origin/bn PPP$ GDP	0.6	30	
6.1.3	Utility models by origin/bn PPP$ GDP	0.3	39	○
6.1.4	Scientific & technical articles/bn PPP$ GDP	31.2	8	● ◆
6.1.5	Citable documents H index	29.3	30	
6.2	Knowledge impact	48.3	23	
6.2.1	Growth rate of PPP$ GDP/worker, %	(0.2)	88	○
6.2.2	New businesses/th pop. 15–64	5.0	26	
6.2.3	Computer software spending, % GDP	0.7	8	●
6.2.4	ISO 9001 quality certificates/bn PPP$ GDP	24.0	15	● ◆
6.2.5	High- & medium-high-tech manufactures, %	0.2	46	
6.3	Knowledge diffusion	24.1	45	
6.3.1	Intellectual property receipts, % total trade	0.2	47	
6.3.2	High-tech net exports, % total trade	3.0	46	
6.3.3	ICT services exports, % total trade	1.8	58	
6.3.4	FDI net outflows, % GDP	2.5	24	
	Creative outputs	**43.4**	**26**	
7.1	Intangible assets	61.0	10	● ◆
7.1.1	Trademarks by origin/bn PPP$ GDP	93.9	17	● ◆
7.1.2	Industrial designs by origin/bn PPP$ GDP	10.6	11	● ◆
7.1.3	ICTs & business model creation†	77.9	14	●
7.1.4	ICTs & organizational model creation†	64.0	30	
7.2	Creative goods & services	31.4	35	
7.2.1	Cultural & creative services exports, % total trade◷	0.5	27	
7.2.2	National feature films/mn pop. 15–69	4.2	47	
7.2.3	Entertainment & Media market/th pop. 15–69	33.8	22	
7.2.4	Printing & other media, % manufacturing	1.3	39	
7.2.5	Creative goods exports, % total trade	2.2	24	
7.3	Online creativity	20.2	36	
7.3.1	Generic top-level domains (TLDs)/th pop. 15–69	18.8	29	
7.3.2	Country-code TLDs/th pop. 15–69	38.5	16	●
7.3.3	Wikipedia edits/mn pop. 15–69	23.4	46	
7.3.4	Mobile app creation/bn PPP$ GDP	7.9	61	○ ◇

NOTES: ● indicates a strength; ○ a weakness; ◆ an income group strength; ◇ an income group weakness; * an index; † a survey question.
◷ indicates that the country's data are older than the base year; see Appendix II for details, including the year of the data, at http://globalinnovationindex.org.
Square brackets indicate that the data minimum coverage (DMC) requirements were not met at the sub-pillar or pillar level; see page 215 of this appendix for details.

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APPENDIX 3. MARKS OF SPAIN IN THE DIFFERENT INDEXES AND PILLARS OF THE GLOBAL INNOVATION INDEX 2018

SPAIN

GII 2018 rank
28

Output rank	Input rank	Income	Region	Efficiency ratio	Population (mn)	GDP, PPP$	GDP per capita, PPP$	GII 2017 rank
27	23	High	EUR	36	46.4	1,768.6	38,286.0	28

		Score/Value	Rank	
	Institutions	**78.2**	**28**	
1.1	Political environment	73.9	31	
1.1.1	Political stability & safety*	75.9	39	
1.1.2	Government effectiveness*	72.9	26	
1.2	Regulatory environment	78.0	32	
1.2.1	Regulatory quality*	70.0	31	
1.2.2	Rule of law*	70.8	31	
1.2.3	Cost of redundancy dismissal, salary weeks	17.4	69	○
1.3	Business environment	82.7	26	
1.3.1	Ease of starting a business*	86.7	69	○
1.3.2	Ease of resolving insolvency*	78.7	18	
	Human capital & research	**47.5**	**26**	
2.1	Education	53.8	45	
2.1.1	Expenditure on education, % GDP	4.3	73	○
2.1.2	Government funding/pupil, secondary, % GDP/cap	22.2	41	
2.1.3	School life expectancy, years	17.9	10	●
2.1.4	PISA scales in reading, maths & science	491.4	27	
2.1.5	Pupil-teacher ratio, secondary⌚	12.0	42	
2.2	Tertiary education	42.2	33	
2.2.1	Tertiary enrolment, % gross	91.2	5	● ◆
2.2.2	Graduates in science & engineering, %	23.9	34	
2.2.3	Tertiary inbound mobility, %	2.7	66	○ ◇
2.3	Research & development (R&D)	46.4	21	
2.3.1	Researchers, FTE/mn pop.	2,719.7	30	
2.3.2	Gross expenditure on R&D, % GDP	1.2	31	
2.3.3	Global R&D companies, top 3, mn US$	74.8	14	●
2.3.4	QS university ranking, average score top 3*	50.1	20	
	Infrastructure	**62.8**	**11**	●
3.1	Information & communication technologies (ICTs)	84.2	14	●
3.1.1	ICT access*	79.8	26	
3.1.2	ICT use*	72.3	26	
3.1.3	Government's online service*	91.3	11	●
3.1.4	E-participation*	93.2	7	● ◆
3.2	General infrastructure	44.4	45	
3.2.1	Electricity output, kWh/cap	5,835.2	35	
3.2.2	Logistics performance*	77.0	23	
3.2.3	Gross capital formation, % GDP	20.6	78	○
3.3	Ecological sustainability	59.9	7	● ◆
3.3.1	GDP/unit of energy use	12.8	24	
3.3.2	Environmental performance*	78.4	12	●
3.3.3	ISO 14001 environmental certificates/bn PPP$ GDP	8.1	11	● ◆
	Market sophistication	**59.4**	**16**	
4.1	Credit	53.8	23	
4.1.1	Ease of getting credit*	60.0	61	○
4.1.2	Domestic credit to private sector, % GDP	111.3	22	
4.1.3	Microfinance gross loans, % GDP	n/a	n/a	
4.2	Investment	46.0	46	
4.2.1	Ease of protecting minority investors*	70.0	24	
4.2.2	Market capitalization, % GDP	64.9	26	
4.2.3	Venture capital deals/bn PPP$ GDP	0.0	28	
4.3	Trade, competition, & market scale	78.5	12	●
4.3.1	Applied tariff rate, weighted mean, %	1.6	19	
4.3.2	Intensity of local competition†	75.8	22	
4.3.3	Domestic market scale, bn PPP$	1,768.6	16	◆

		Score/Value	Rank	
	Business sophistication	**37.8**	**40**	
5.1	Knowledge workers	50.7	34	
5.1.1	Knowledge-intensive employment, %	33.2	40	
5.1.2	Firms offering formal training, % firms	n/a	n/a	
5.1.3	GERD performed by business, % GDP	0.6	30	
5.1.4	GERD financed by business, %	45.8	31	
5.1.5	Females employed w/advanced degrees, %	22.1	18	
5.2	Innovation linkages	28.3	67	◇
5.2.1	University/industry research collaboration†	41.0	64	○
5.2.2	State of cluster development†	55.1	35	
5.2.3	GERD financed by abroad, %	8.0	47	
5.2.4	JV–strategic alliance deals/bn PPP$ GDP	0.0	73	○
5.2.5	Patent families 2+ offices/bn PPP$ GDP	0.6	30	
5.3	Knowledge absorption	34.5	43	
5.3.1	Intellectual property payments, % total trade	1.3	24	
5.3.2	High-tech net imports, % total trade	7.6	69	○
5.3.3	ICT services imports, % total trade	1.7	35	
5.3.4	FDI net inflows, % GDP	2.7	62	
5.3.5	Research talent, % in business enterprise	37.0	34	
	Knowledge & technology outputs	**38.9**	**23**	
6.1	Knowledge creation	31.3	31	
6.1.1	Patents by origin/bn PPP$ GDP	2.6	39	
6.1.2	PCT patents by origin/bn PPP$ GDP	0.8	29	
6.1.3	Utility models by origin/bn PPP$ GDP	1.4	20	
6.1.4	Scientific & technical articles/bn PPP$ GDP	21.1	24	
6.1.5	Citable documents H index	58.4	12	●
6.2	Knowledge impact	50.4	16	
6.2.1	Growth rate of PPP$ GDP/worker, %	0.5	63	○
6.2.2	New businesses/th pop. 15–64	3.2	39	
6.2.3	Computer software spending, % GDP	0.7	5	● ◆
6.2.4	ISO 9001 quality certificates/bn PPP$ GDP	20.4	17	
6.2.5	High- & medium-high-tech manufactures, %	0.4	26	
6.3	Knowledge diffusion	34.8	24	
6.3.1	Intellectual property receipts, % total trade	0.5	25	
6.3.2	High-tech net exports, % total trade	3.9	40	
6.3.3	ICT services exports, % total trade	3.0	33	
6.3.4	FDI net outflows, % GDP	4.2	14	
	Creative outputs	**41.5**	**29**	
7.1	Intangible assets	55.1	23	
7.1.1	Trademarks by origin/bn PPP$ GDP	56.1	38	
7.1.2	Industrial designs by origin/bn PPP$ GDP	12.9	9	● ◆
7.1.3	ICTs & business model creation†	74.1	24	
7.1.4	ICTs & organizational model creation†	59.9	42	
7.2	Creative goods & services	28.2	46	
7.2.1	Cultural & creative services exports, % total trade	n/a	n/a	
7.2.2	National feature films/mn pop. 15–69	7.7	19	
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7.3.3	Wikipedia edits/mn pop. 15–69	58.8	17	
7.3.4	Mobile app creation/bn PPP$ GDP	26.8	35	

NOTES: ● indicates a strength; ○ a weakness; ◆ an income group strength; ◇ an income group weakness; * an index; † a survey question.
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Source: taken from [5] with permission

REFERENCES:

1. Castells, Manuel (2010) The Rise of the Networked Society (2nd edition) Wiley Blackwell, MA, USA
2. Gibbons, Michael; Limoges, Camille; Nowotny, Helga; Schwartzman, Simon; Scott, Peter and Trow, Martin (1997) The new production of knowledge. The Dynamics of Science and Research in Contemporary Societies. Sage Publ. Ltd., Los Angeles, USA
3. Global Innovation Index (2018) In https://www.globalinnovationindex.org/Home
4. Kelly, Kevin (1998) New rules for the new economy. Fourth State, London
5. Kurzweil, Ray (2005) The Singularity is Near. Viking Books, New York
6. Manyika, James; Chui, Michael; Bughin, Richard; Dobbs, Jacques; Bisson, Peter; Marrs, Alex (2013) Disruptive technologies: Advances that will transform life, business, and the global economy. McKinsey Global Institute
7. UNESCO. World Culture Report: Culture, Creativity, and Markets. Paris: UNESCO, 1998.

INNOVATION IN TODAY'S SOCIETY

SOCIAL ACCEPTANCE OF INNOVATION

Aleix Pons and
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INTRODUCTION

From Schumpeter until the most recent update of the Oslo Manual by the OECD, innovation has been a phenomenon that has been analysed and studied from multiple perspectives. In reality, the concept of innovation has mutated as many times as the authors have asked the questions. The definition has evolved from the classic 'invention that is introduced into the market' by Schumpeter (1911) to expanded versions such as that included in the latest version of the Oslo Manual (2018), which considers innovation to be 'a product or a process (or a combination thereof) that is new or significantly improved with respect to the unit's previous products and process and that has been made available to potential users (product) or has been brought into use by the unit (process)'.

For the Fundación Cotec (2015), innovation is 'any change (not only technological) based on knowledge (not only scientific) which create value (not only economic)'. In order for innovation to happen, all three elements need to exist together, without exception. These three factors are fundamental in distinguishing innovation from other concepts that could be similar in many ways. In the history of humanity, there are many changes that create value but that are not based on knowledge. They are serendipities. In much the same way, in traditions there is knowledge and value but it is clear that they do not have any element of change. Equally, a change based on knowledge which creates no value is a simple occurrence. The proposal of Cotec implies, therefore, widening the parameters of the definition to include new manifestations of the phenomenon that do not match many other definitions, such as in the case of social innovation, open innovation, or innovation that occurs in the public sector.

In any case, a relevant part of existing literature on the topic has tended to consider society as a 'passive user' of innovation, omitting its deciding role in any technological advance (Acevedo Pineda, 2010).

Therefore, Cotec considers that, within

the context of accelerated technological change that is currently happening, social perception of innovation is a crucial factor for analysis.

Consequently, Cotec has recently sought to challenge Spanish society's perception of society through two complementary approaches. The first was a more traditional approach and involved two rounds of public opinion surveys of a wide range of people. The second was slightly less conventional and involved a laboratory experiment using the methodology of behavioural economics. In the following sections, the reader will be presented with the principal findings of these two projects as well as the researchers' final conclusions.

TWO APPROACHES TO THE SOCIAL PERCEPTION OF INNOVATION

Cotec has recently brought together social perception of innovation in society in general and the impact that this has on technological change on the labour market in particular using two complementary methods. The first was a public opinion survey that had two rounds a year apart and was aimed at society as a whole and created in collaboration with SIGMADOS. The second made use of a pioneering method in Spain following a methodology confirmed by Behavioural Economics and developed in collaboration with the Mixed Unit for Research of Behaviour and Social Complexity (UMICCS).

Survey of social perception of innovation in Spanish society

In spring 2017, Cotec launched the first round of the public opinion survey on the social perception of innovation, in collaboration with the demoscopic company Sigmados. It is the largest-scale survey on this topic carried out in Spain to date. It included 2,400 interviews throughout the country and was comprised of 27 questions divided into two groups (perception of innovation in Spain and the impact of technological change on the labour market). A sample of this size allows for a reduction in the margin of error for aggregated data of up to ±2,05% with a confidence interval of 95.5%.

In the summer 2018, the second round of the survey was completed and Cotec's interest in continuing this initiative with an annual frequency was confirmed. It was observed in both rounds of the survey that the variables which determine the greatest differences in the perception of innovation and its socioeconomic effects are linked to the occupation of the interviewee as well as their income threshold and level of education much more than their vote reminder, age or gender.

The main results of this survey are outlined below.

Perception of innovation in Spain

The first section of the survey is based on the broad concept of innovation as promulgated by Cotec. A large part of the questions is inspired by or use the study "Innovation Population. The UK's views on innovation (2014)", as reference. It was designed by NESTA in collaboration with ComRes, a fact that means that the results of Spain and the UK can be compared.

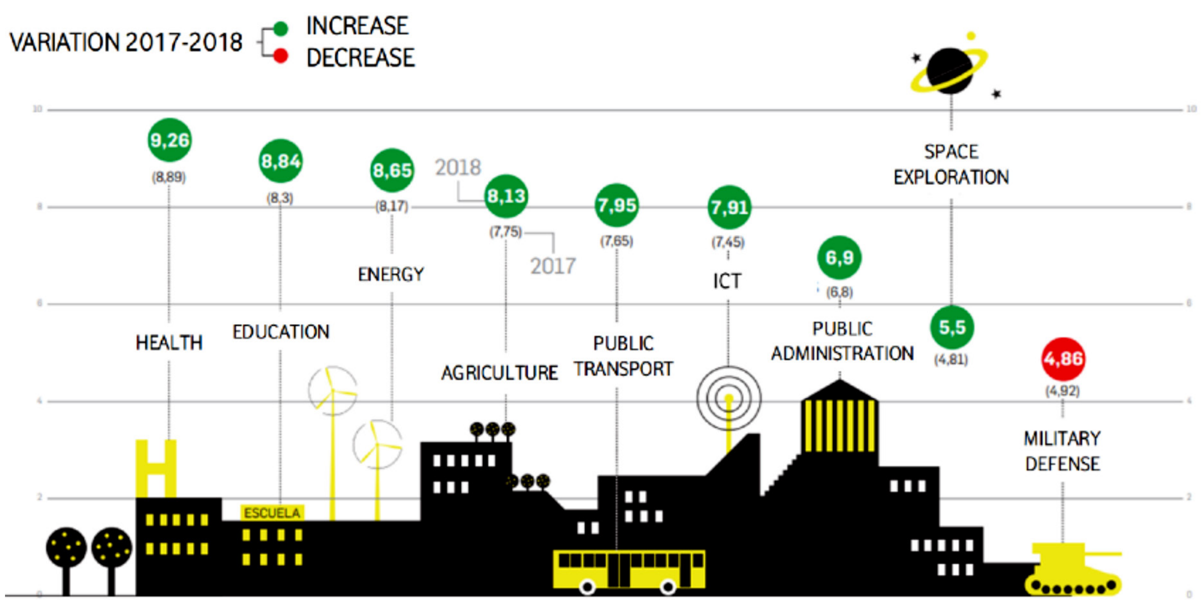
Spanish society has an overwhelming positive view of the phenomenon of innovation, although it is more and more conscious of the challenges, risks and opportunities that technological change means. In 2018, eight out of ten citizens considered innovation to be 'positive' (compared to 4.5% who consider it to be negative and the 13.3% who consider it neither positive nor negative). This perception, however, decreased over the course of a year, because in 2017, the percentage of participants with favourable views on the topic was as high as 90%.

Furthermore, there is a rather generalised belief about the need for innovation in a variety of economic sectors, going beyond that of industry or of strictly technological nature. In fact, citizens highlighted healthcare, education and energy (in that order) as priority areas for innovation. This finding largely coincides with what was seen in the UK, where the energy sector came in second place beaten only by healthcare.

On the other hand, 80% of those questioned consider the commitment for R&D&I in both the public sector and private to be insufficient. Moreover, they consider that the current regulatory framework does not adequately support its development (70%). These figures are unchanging in both rounds of the survey.

However, if the country's innovation performance is compared with that on a global level, it is surprising that more than half of the population (54%) consider that Spain innovates at a level similar to the European Union average. And, in fact, only a third of the population places Spain below average with regard to this question within a European context. This belief does not correlate with the reality, given that R&D in Spain is markedly below the European average (1.2% of GDP in 2017 compared to 2,07% for the EU) and that the Spanish economy is classified as having 'moderate innovation' (the third

FIGURE 1. WHICH AREAS DO YOU CONSIDER MOST IMPORTANT FOR INNOVATION TO TAKE PLACE?



Source: Fundación Cotec

of four possible categories) in the European Innovation Scoreboard. This perception is strongly conditioned at the professional level of citizens, with business people and managers being the most critical, almost half of which believe that the country falls into the least advanced group in the EU regarding this topic.

Finally, citizens have embraced new business models emerging from digital fields, both from a user point of view (46%) as well as those who offer products and services (25% state that they receive some income from online platforms).

Impact of technological change on the labour market

Just like in previous industrial revolutions, the so-called fourth industrial revolution has re-opened classic debates on economy and society and how they relate to technological change and volume of employment. And this one introduces another of an ethical nature.

The Spanish foresee a near future in which 'the machines' (robots, computers, algorithms) will play a greater role in the labour market and are seen to be increasingly worried about the socioeconomic implications that this will entail.

Similarly, two thirds of the population consider that 'many' or 'quite a lot' current job positions will be filled by robots or computers in the near future of 15 years. This is a common belief and independent of the interviewee's profile. There are relatively few who believe that the number of jobs at risk of automatization are only 'some' (23%) or 'few' (9%).

At the same time, the perception of the disruptive nature of continual technological change has gained ground. Although the percentage of the population that limits the potential of automatization to strictly routine tasks is still the majority (55%), the proportion of people who consider that artificial and robotic intelligence will be able to undertake tasks of a more creative nature also (37% in 2018, up 3 points from 2017).

In any case, there seems to be a clear perception that the labour market is a dynamic entity, resulting from steady creative flows and destruction of jobs, perhaps due to the high rate of temporary posts which is higher than the European average.

The big question which divides the Spanish population into two very equal halves centres on the ability that this fourth industrial revolution is thought to be able to compensate the level of job losses with that of the creation of new jobs. In 2018, 49% of Spanish citizens stated their belief that technological change would have a destructive effect on jobs as opposed to the 44% who understood that it would in fact create jobs. Moving beyond this snapshot of a certain point in time, it is necessary to point out the temporal nature of the public's perception of this issue. In this sense, there is a trend towards greater pessimism, since in 2017, there was a clear majority that was convinced of the positive net effect on employment (51% versus 44%).

It would be too speculative to attempt to identify a single explanatory factor behind this more pessimistic perception. It is most likely to be a combination of factors, including the proliferation of studies and negative information in the media about the future of employment as well as growing prominence in the public area of labour conflicts related to new digital business models (such as the taxi-private hire car conflict).

It is interesting, however, to point out the presence of a certain sense of immunity in this scenario of change when citizens are asked to consider the potential effect on their own jobs. In 2018, 57% of those who were employed at the time considered that their jobs were not under threat from the process of automatization, which is 10% higher than in 2017. This type of dissociation between the perception of the general situation and the individual situation is not entirely anomalous. In fact, it is often seen in surveys of economic sentiment, such as those published by the Centre for Sociological Research (CIS).

However, this is compatible with the existence of a relevant group of the active population, making up 36% of the total, which acknowledges the feeling of not being prepared to compete in an increasingly automatized and digitalized labour market. Specifically, approximately 7.5 million people acknowledge that they are in a vulnerable situation. This group should be given priority when it comes to attention by public authorities and social partners.

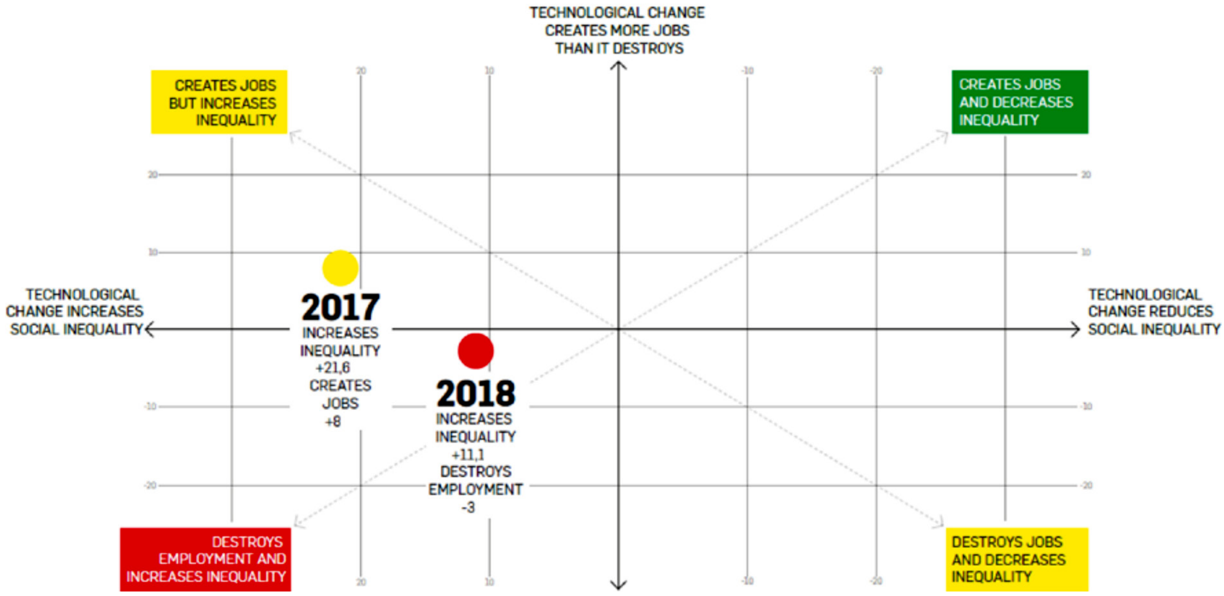
The Spanish, therefore, are very divided when it comes to anticipating whether technological change is or is not a net generator of jobs. However, they do seem to veer towards its potential negative effects in terms of social inequality; 49% believe that this change increases levels of social inequality, which is nine percent more than those who think otherwise (38%). It should be noted, however, that in the first round of the survey the difference between the two was even more striking, with a difference of 21.6% (56.5% to 34.9%).

In summary, the comparison of the two rounds of the demographic study reveals that citizens are becoming more concerned about the impact of technological change. In 2017, the effect of technological change on social inequality was a concern for some. In 2018, the same concern is present but it now extends to employment levels.

Figure 2 shows this change of Spanish public opinion for the period studied. It represents social perception on the net impact of technological change based on two variables: volume of employment and levels of social inequality. For both of the surveys – 2017 and 2018 – the points are plotted based on the net balance between the answers to the two binary response questions asked: ‘Do you think that technological change creates more jobs than it destroys?’ and ‘Do you consider that technological change increases social inequality?’.

Spanish public opinion appears to have shifted from the second to the third quadrant, meaning that there is generally more concern about one of the two variables (social inequality) instead of about both (inequality and employment).

FIGURE 2. SOCIAL PERCEPTION OF THE NET IMPACT OF TECHNOLOGICAL CHANGE ON VOLUME OF EMPLOYMENT AND SOCIAL INEQUALITY LEVELS. 2017-2018.

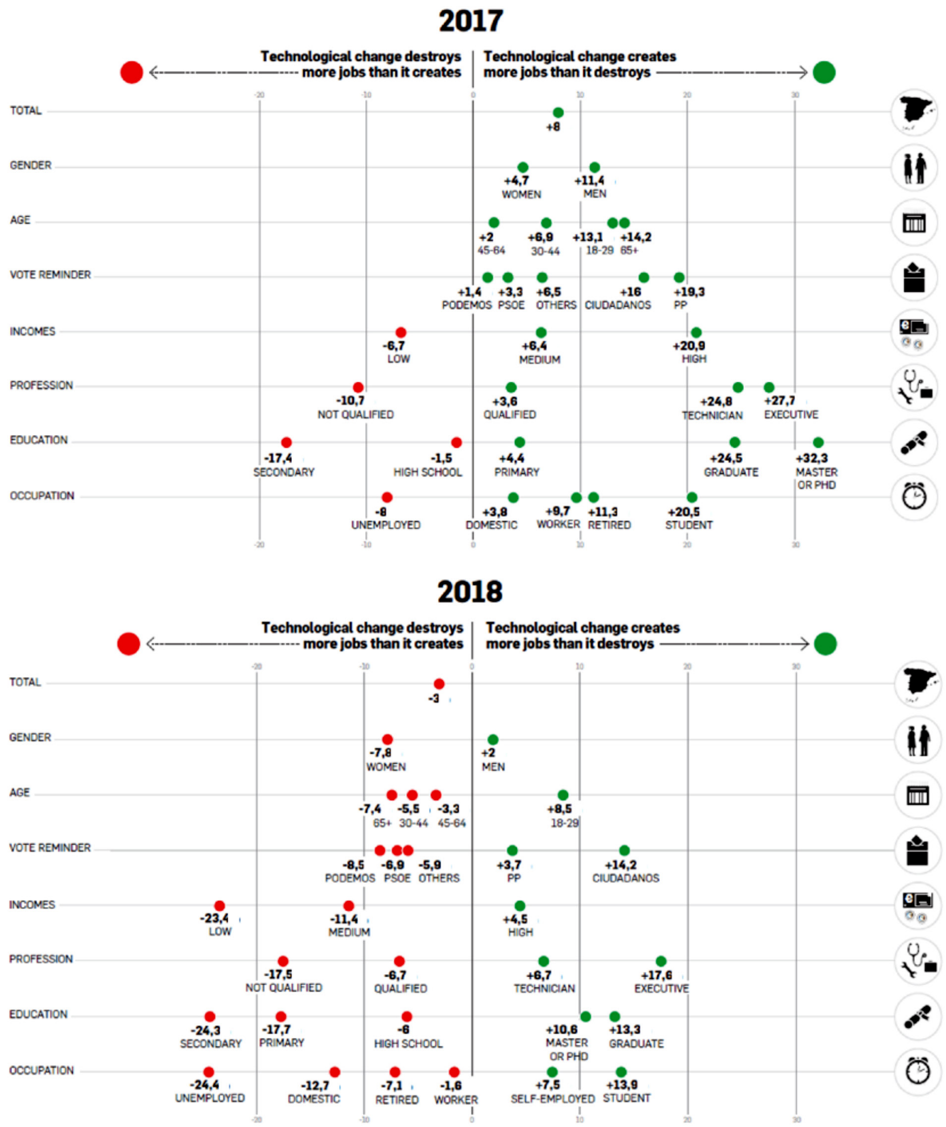


In 2017 the positive net balance between those who believe that technological change is a net generator of employment (51.6%) and those who think otherwise (43.6%) is +8. On the other hand, the net balance between those who believe that inequality increases (56.5%) and those who think it is reduced (34.9%) is +21.6. In 2018, the positive net balance between those who believe that technological change is a net generator of employment (45.9%) and those who believe otherwise (48.9%) is -3. On the other hand, the net balance between those who believe that inequality increases (49%) and those who think it decreases (38%) is +11.1.

Source: Fundación Cotec

The sample size is sufficient to fully represent attitudes towards technological change in a disaggregated manner. Using the seven categories that characterize the sample (gender, age, vote reminder, incomes, education level and profession and occupation) it is possible to analyse the answers from a total of 28 segments of interest individually.

FIGURE 3. SOCIAL PERCEPTION OF THE IMPACT OF TECHNOLOGICAL CHANGE ON THE VOLUME OF EMPLOYMENT ACCORDING TO 28 DIFFERENT CATEGORIES. 2017-2018.

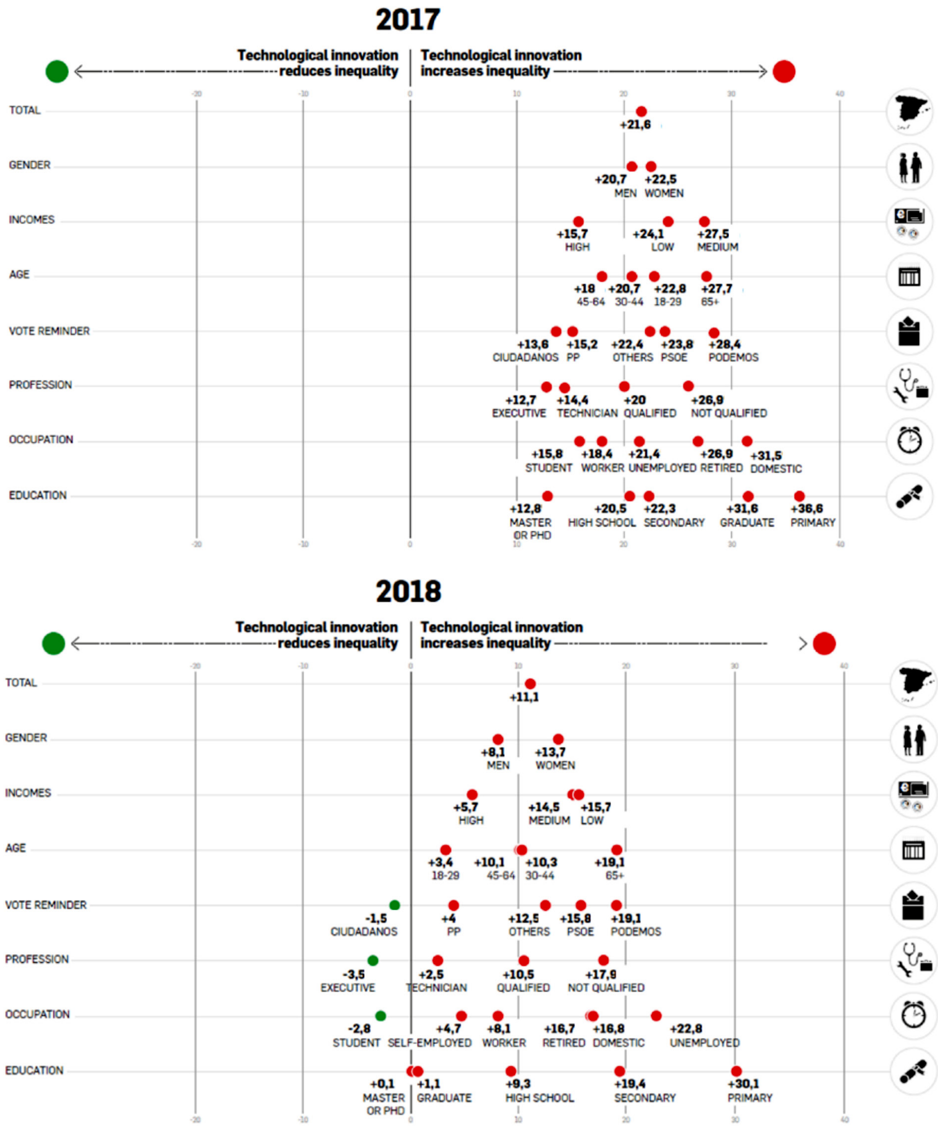


The figure shows the difference for each segment of the population between those who believe that technological change 'creates more jobs than it destroys' and those who think that it 'destroys more jobs than it creates'. For example, for the population as a whole (+8 in 2017), it is the difference between 51.6% and 43.6%.

Source: Fundación Cotec

The concern about the effects of technological change on the levels of social cohesion is much more transversal among the different segments of the population than what exists in relation to the volume of employment. For this aspect of the study, in 2017 the 28 groups that were analysed were unanimously pessimistic when asked about social inequality. In 2018, practically all (25 of the 28 groups) remained pessimistic with regard to this issue, although the three specific segments (namely executives, students and Ciudadanos voters) that were the exceptions believe that technological change will contribute to decreasing social inequality levels.

FIGURE 4. SOCIAL PERCEPTION OF THE IMPACT OF TECHNOLOGICAL CHANGE ON SOCIAL INEQUALITY IN 28 DIFFERENT CATEGORIES. 2017-2018.



The figure shows the difference for each segment of the population between those who believe that technological change ‘increases social inequality’ and those who believe that it ‘decreases inequality’. For example, for the entire population in 2017 (+21.6) it is the difference between 57% and 35%.

Source: Fundación Cotec

The survey asked participants about the Universal Basic Income (RBU), a possible tool of economic policy that usually is starting to appear more frequently in discussions of an academic or political nature that are about social inequality. Universal Basic Income, also referred to as Unconditional Basic Income, is a form of social security in which all citizens or residents of a country regularly receive, no strings attached, a sum of money from either a government or another public institution, regardless of any other income received. In 2018, more than half of the Spanish population (54%) sympathize with the idea of some kind of universal basic income mechanism. However, only 38% of them would be willing to assume a tax increase that would generate funds to pay for it.

As discussed above, the concern about a possible deterioration of the level of social cohesion linked to technological progress exists and is very much transversal in character. However, citizens are able to discriminate and place different value on the implications of technological change on other types of rifts: the gender gap and the balancing of personal and work life. In such cases, six out of ten Spaniards consider that technology and automatization will make closing the gap easier, with this opinion being fairly homogenous in all analysed groups. On the other hand, more than half of the respondents (55%) believe that technology will help reduce the labour gap between men and women (both in terms of salary and participation in the work force), although there is a slight difference of opinion by gender, with women being more pessimistic (34% of the women surveyed believe that technology will not help reduce the gender gap) than men (31%).

Cotec Behavioural Economics Lab: automatization and the labour market

In autumn 2018, Cotec presented the results of its Behavioural Economics Lab's (LEC) first experiment. This was a joint initiative with the Mixed Unit for Research of Behaviour and Social Complexity (UMICCS) and was headed by professors Antonio Cabrales, Penelope Hernández and Anxo Sánchez. Behavioural economics seeks to model the behaviour of individuals by incorporating ideas and concepts from other fields such as psychology and sociology into economic theory ideas, while experimental economics functions as a methodology to verify and validate theories and hypotheses through the development of laboratory experiments. For the first time in Spain, behavioural economics has been used to answer questions related to automatization and the labour market: what variables will influence the implementation of automatization and how will they do it? What effects will it have on incomes, jobs, productivity and production? What role can economic policies play in overcoming potential risks?

The methodology used had the aim of transparently replicating the decision context of those involved in this market, that is to say workers and managers, in order to understand the effects of economic policies on the labour market of the future. In these experiments, the workers perform production tasks and make executive decisions, deciding between workers and/or robots to perform these tasks. Thanks to the collaboration of the Laboratory of Experimental Economics and Behaviour (LINEEX) at the University of Valencia, experimental sessions were held in which 900 individuals participated. These participants were chosen because of their training and skills and were considered to be representative of the population that will enter the future labour market. In accordance with the experiment's methodology, participants received a monetary token based on their performance in the tasks, which encouraged them to make decisions that resulted in the greatest benefit, as would occur in the labour market. This makes this type of research completely different from other forms of evaluation, such as surveys, in which responding in one way or another has no direct implication for the interviewees. Therefore, the former approach is closer to the scenario being studied.

The sample was divided into groups and various regulatory, fiscal and productivity scenarios were analysed. These included the introduction of a basic income, taxes on the replacement of workers by machines, situations of sharing working hours between human workers and robots, and situations of replacement of workers by machines. Thanks to this design of multiple scenarios and the large number of participants in the experiments, it was possible to obtain a fairly complete picture of the automatization process and its social perception. The main conclusions of this experiment, which should not be taken as universal truths but should instead be used as a starting point for further consideration, are:

- The threat of being replaced by a robot does not affect the workers' productivity. Workers do not vary their production depending on whether or not there is a risk of being replaced by a robot.
- Neither the basic income nor a tax for replacing a worker with a robot decreases worker productivity. In fact, the existence of a basic income that provides the worker with a default salary does not negatively affect their efficiency. On the other hand, the worker, aware of the replacement tax incurred by a manager when being replaced, does not reduce their productivity due to feeling less vulnerable.
- The tax on the substitution of a worker reduces the likelihood of replacement. Managers perceive the added cost to be high enough already, so they will only use a robot when the increase in productivity when compared to the worker is enough to offset this cost.
- The worker does not increase their productivity when they have not been replaced by a more efficient robot. Although it might be reasonable to expect an additional effort on behalf of the worker as a response to having kept their position when it was possible for them to be replaced, this does not happen.

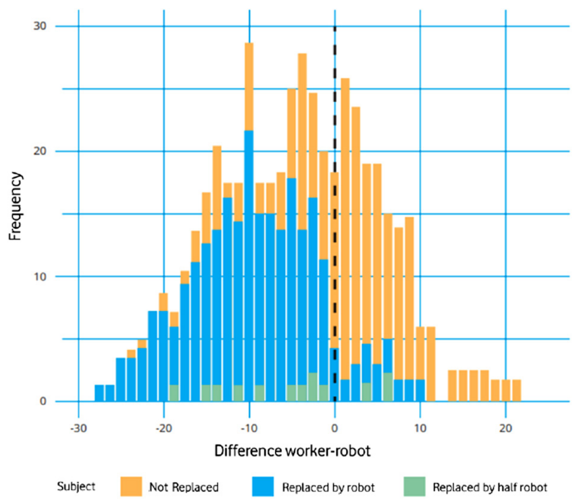
From a macroeconomic point of view, this study provides some additional conclusions:

- In companies which adopt automatization, productivity increases. This increase is exclusively due to the new installed processes and not because there is an incentivising effect on the workers who have not been replaced. On the other hand, it is difficult to defend a stance on the effects of the general balance. The higher productivity in some sectors can increase the size of said areas and therefore increase overall productivity.
- Not all potentially automatable jobs are replaced by machines. In fact, the existence of 'social preferences' on behalf of the executives, who choose to keep their workers in 30% of cases where they can employ a robot/algorithm that is up to 19% more productive than their workers, has been observed. In any case, in order to study the consequences from the point of view of aggregate employment, it is necessary to study the indirect effect

and the substitution effect in other sectors. The experience of previous industrial revolutions suggests that long-term employment rates are not related to the replacement of workers by robots in different sectors.
- The option of replacing the worker via a part-time or shared-day contract is not attractive. Managers when offered this immediate option almost never choose it, instead preferring to replace or not the worker entirely by a robot.

Figure 5 shows the histogram of results of the Cotec Behavioural Economics Lab experiment, illustrating the complete casuistry of situations, according to whether or not the decision (complete or partial) to automatize a certain process is made.

FIGURE 5. HISTOGRAM SHOWING THE DIFFERENCE BETWEEN THE PRODUCTION OF A WORKER AND A ROBOT IN THE FIRST PHASE



Source: Fundación Cotec

Despite its limitations, we consider this to be a pioneering line of research that has great potential for development and that can contribute enormously to public policy design.

CONCLUSIONS

The interpretation of a wider definition of the concept of innovation, such as the one suggested by the Fundación Cotec - any change (not only technological) based on knowledge (not only scientific) which create value (not only economic)' – allows for different manifestations of the phenomenon to be included, whereas they are not covered by other definitions, namely social innovation, open innovation or innovation which occurs in the public sector.
In any case, one of the most determining elements of the existence, impulse or adoption of innovation is the human factor. This is why Cotec wanted to bring together the social perception of innovation in general and the impact that society considers that technological change has on the labour market in particular. It has done so by use of two complementary approaches. First, through a more traditional approach of conducting a survey of a large sample of the population. And secondly by means of a less conventional approach that comprised of a laboratory experiment using the methodology of behavioural economics.
The two rounds of the Cotec-Sigmados macro survey on the social perception of innovation in Spain allowed us to confirm that Spanish society has an overall positive view of the phenomenon, although people are becoming increasingly aware of the challenges, risks and opportunities that technological change poses.
- Spanish citizens (80%) consider that the investment into R&D&I in both the public and private sectors is insufficient. At the same time, they stated that the regulatory framework is not

adequate for allowing development (70%).

- Moreover, people have embraced the new business models emerging from digital fields from the perspective of the user (46%) as well as providers of products and services (25% of respondents affirm that they receive some time of income from digital platforms).
- In a consistent way throughout the duration of the two surveys, it was possible to observe that the variables that determine the greatest differences in the perception of innovation and its socioeconomic effects are the profession, occupation, income and level of studies. These have a much greater effect than vote reminder, age or gender.
- All of the findings fit in with the growing concern about the impact that technological change can have both on the levels of social inequality and on the volume of employment in the labour market.
- Between the two rounds of the macro-survey (carried out in the spring of 2017 and in the summer of 2018) there was a significant increase in the size of the group that considers that technological change is a reason for net job destruction (44% from 2017 to 49% in 2018). Greater pessimism that, moreover, occurs consistently in each and every one of the 28 categories into which the respondents were divided (there are still 11 categories believing that innovation is a net generator of employment in 2018 but this view is less strongly held than in 2017).
- Added to this is the acknowledgement by a significant percentage of the active population (36% to be precise, which would equate to more than 7.5 million people) that they do not consider themselves prepared to meet the challenges that the new labour market will pose.

On the other hand, the first experiment conducted by the Cotec's Laboratory of Behavioural Economics (LEC) brings to light the existence of the 'social preferences' that need to be taken into account. This would mean that a sizeable amount of all potentially automatable jobs will not be automatized (in around 30% of possible cases where replacing a worker with a robot that is up to 20% more productive, the replacement does not occur).

REFERENCES:

Acevedo Pineda, E. B. (2010). Innovación tecnológica, economía y sociedad: una reflexión necesaria para CTS. Sala de lectura CTS+ i.

Fundación Cotec para la Innovación (2017). I Encuesta de percepción social de la innovación en España. http://informecotec.es/media/PRESENTACION-ESTUDIO-DEMOSCOPICO_IMAGEN-COTEC_VFINAL.pdf.

Fundación Cotec para la Innovación (2018). II Encuesta de percepción social de la innovación en España. http://informecotec.es/media/II-ENCUESTA-PERCEPCI%C3%93N-SOCIAL-DE-LA-INNOVACI%C3%93N-EN-ESPA%C3%91A.pdf.

Cabrales, A., Hernández, P., Sánchez, A. & Fundación Cotec (2018). Laboratorio de Economía del Comportamiento: Automatización y mercado de trabajo. http://informecotec.es/media/COTEC-Automatizacion-mercado-trabajo.pdf.

Nesta (2014). Innovation Population. The UK's views on innovation. https://media.nesta.org.uk/documents/innovation_population_wv.pdf.

OECD (2018). Oslo Manual 2018, Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition. https://www.oecd.org/science/oslo-manual-2018-9789264304604-en.htm.

THE ROLE OF INNOVATION FROM A GENDER PERSPECTIVE

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INTRODUCTION

The labour market has experienced changes in composition which have increased the gender heterogeneity of the labour force. Over recent decades, and for developed countries and regions, there is evidence of impressive advances by women in areas which include educational attainment and participation in the labour market. There has also been a progressive loss of importance of physical attributes for productivity. Despite these trends, there are still some gender gaps. Firstly, despite women's high qualification, they remain significantly underrepresented in sectors related to science, technology and engineering. Secondly, even when they are involved in innovation, women are less well represented in the upper echelons of the process.

A common motive for promoting gender diversity in teams is to achieve equal opportunities. However, another reason for promoting gender diversity is the expectation that gender-diverse teams will arrive at better decisions, ones more socially responsible, more representative of society, and better performing in channels that including investment, internal management and corporate governance. This empirical evidence is not anecdotal. Access to skilled workers engaged in the process of innovation is crucial, since a more competent stock of workers generating innovations will foster economic growth. In addition to the qualification, recent evidence shows that a more diverse labour force fosters innovation since observable demographic characteristics imply a diversity of competences.

Hence, international policymakers are paying special attention to the promotion of females within the science and innovation system. The rationale for this is not only to equalize access, but also to achieve greater economic growth though increasing the access of skilled female workers to activities where they are less well represented. The importance of incorporating the gender dimension in all innovation processes has been highlighted by different organizations including the European Commission (EC, 2009, 2014, 2019), the Organization for Economic

Cooperation and Development (OECD, 2017) and the World Economic Forum (WEF, 2018).

Having a qualified and diverse team is of steadily increasing importance. The rapid changes in technologies such as Artificial Intelligence, Big Data and Cloud Computing have important implications in terms of the development of technological and non-technological innovations. First, the demand for IT skills may exacerbate gender gaps in economic participation and opportunity; as technological skills gain prominence in the labour markets, the gender gap may increase. Second, the current gender gap implies that this general-purpose technology is being developed across many fields without diverse talent, limiting its innovative and inclusive capacity. Third, the low number of females in IT and the increasing demand for IT skills indicate an opportunity to enlarge the supply of qualified labour.

The energy sector is also transforming with the advance of the technologies. This sector must respond to three major energy policy challenges, the so-called "energy triangle" of market reform, climate change and supply security. Innovation plays a crucial role in achieving all these major goals. As in other sectors, technologies are a key factor in accelerating these innovations. Human resources play a key role in facilitating the adoption of new technologies and sectoral transformation. The energy sector employees in Europe more than 950 thousand workers who generate a production value of more than 850,000 million euros (Eurostat, 2017). Given the high production per worker, and the strategic importance of the sector, introducing gender diversity as a tool to address the challenges is a key issue for public and private agents.

The present section provides an overview of facts about gender and innovation and some policy recommendations. The following one provides an overview of theoretical and empirical results regarding gender and innovation. The third section presents arguments about gender diversity and innovation at the territorial level. The final section is devoted to presenting some policy recommendations.

INNOVATION AND GENDER: A LITERATURE REVIEW

The role of gender diversity in innovation has gained increasing prominence in the academic literature. This interest is due to the major need for evidence bearing on the relationship between a more gender diverse workforce participating in the innovation process, and the need for fostering productivity and economic growth. At the theoretical level, knowledge production depends on the labour force and the stock of knowledge (Romer, 1990; Grossman and Helpman, 1994; among others). The number of researchers in an economy is basic in order to foster the knowledge production. However, as R&D and innovation activities have increased their complexity, there is a greater need to have access to employees and networks with more diversity knowledge and capacities (Barabási, 2005; Jones, 2009). Hence, not only the number, but also the gender diversity, of researchers is crucial in producing innovation and fostering economic growth.

The literature analysing the relationship between gender diversity and firm performance is very wide. In these analyses, the concept of gender widens the biological definition of sex. Hence, a gender analysis expands the understanding of mechanisms that cause differences in behaviour, outcomes, and perceptions, with the aim of producing more focused and accurate analysis. The main assumption of these studies is that cognitive patterns tend to vary systematically with observable demographic characteristics such as gender (Thomas and Ely, 1996; Campbell and Minguez-Vera, 2008). These differences may affect the decisions taken in the firm and the performance of the firm. Despite this variation, the empirical analyses in the innovation literature are usually gender neutral. However, such literature as has analysed the relationship between diversity and innovation, has generated somewhat controversial theoretical and empirical arguments.

On the one hand, previous research has found that teams composed of employees with diverse cognitive capabilities in terms of skills, knowledge, preferences, abilities and perspectives foster a firm's innovative capabilities (Laursen, 2012; Parrotta et al., 2014; Østergaard et al., 2011). There are several mechanisms underlying this effect. First, diversity generates higher quality decisions due to the achievement to a broader consensus between all the members of the team (Huberman, 1990; Amason, 1996; Hong and Page, 2001, 2004). Second, diversity avoids the sub-optimal decisions that arise when individuals favour members of their own group (King et al., 2011; Lee, 2015). Third, innovations usually are the result of complex tasks which require problem-solving. The greater the variety of ideas, information and perspectives that exists in the team, the more alternatives that are evaluated and, consequently, the more innovative solutions generated, particularly during the development stage of innovations (Miller and Triana, 2009). Fourth, diversity leads to a better understanding of complex tasks (Campbell and Minguez-Vera, 2008). Consequently, diversity helps in absorbing and in adapting external knowledge to generate innovations at firm level (Nooteboom et al., 2007). To sum up, gender diversity might enhance a team's effectiveness.

TABLE 1. PROS AND CONS OF GENDER DIVERSITY ON TEAM PERFORMANCE

PROS	CONS
- Gender-diverse teams have a wider diversity of skills and abilities; - Gender-diversity leads to broader representation of preferences and perspectives; - The decisions will be better - The problem-solving process will be more efficient; - The problem solution process of complex tasks will be executed more easily.	- Diverse teams may have higher levels of distrust, misunderstandings and emotional conflicts; - The process of decision-making may be more time consuming and less effective; - There are short-term adjustment costs during the process transition to a more gender diverse team.

Source: own elaboration

Conversely, there are some theoretical arguments justifying the existence of certain negative impacts or frictions. Research suggests that demographic diversity has the potential to generate difficulties in the interaction process among team members. First, diversity may create distrust, misunderstandings and emotional conflicts. The main reason is the existence of divergent vocabularies, priorities and paradigms. According to Chowdhury (2005), people tend to categorize others and perceive their own category as superior. This behaviour produces ineffective communication and non-cooperation. However, Pelled et al. (1999) do not find any significant impact of gender on emotional conflict. Second, difficulties in the decision-making process will make it more time consuming and less effective (Lau and Murnighan, 1998). Third, at least in the short term, the transition to greater diversity adversely affects performance, in part due to adjustments in the team dynamics.

Consequently, these arguments suggest that diversity enriches a team with diverse cognitive endowments which foster innovation, creativity and overall performance. However, it has the potential to generate certain frictions (Lazear, 1999; Basset-Jones, 2005; Chowdhury, 2005). In response to these ambiguous results, researchers have suggested an inverted U-shaped relationship between diversity and innovation (Nooteboom et al., 2007; Østergaard et al., 2011; Laursen, 2012; Lee, 2015). In other words, firms with low gender diversity will increase their innovation if they increase their diversity ratio. However, beyond a certain ratio, the negative effects outweigh the positive effects and the innovation effects decrease. An explanation of the non-linear relationship is that firms need related variation in knowledge and skills to optimize their learning capacity. Hence, there appears to be an optimal diversification ratio where firms maximize their innovation capacity.

Finally, we should make two observations. First, gender diversity interacts with other characteristics in the workplace—for instance, occupation level and qualification are key issues. Hence, it is not only important to analyse gender diversity, but also how this characteristic interacts with others. Second, a key issue is that, in order to analyse the impact that gender diversity has on innovation, we cannot restrict results to the level of the individual. For example, some studies suggest that women are generally more risk-averse than men and are less competitive. However, most such studies are based on the individual. Consequently, because teams may show their own idiosyncrasies, it may not be valid to extrapolate individual level results to the group level.

THE TERRITORIAL DIMENSION OF GENDER AND INNOVATION

Firms are located in particular territories and, consequently, it is necessary also to incorporate a dimension in which the characteristics of the territory's labour market, R&D endowments, social capital and policies affect the firm performance. The literature analysing the impact on the gender diversity and innovation is mainly at the firm level. However, in each territory, employees with certain characteristics will have higher or lower productivity depending on its existing stock of knowledge, and also on the facility to access its R&D endowments. Hence, the analysis of the effect of gender diversity on innovation and knowledge generation should also consider these regional particularities.

The mechanisms of how diversity in a region affects the generation of new knowledge is via each individual's capacity to perceive, assess and commercially exploit new knowledge (Audretsch et al., 2010). The diverse agents form a "melting pot" (Forida, 2002) which increases their learning capacity and knowledge spillovers across all agents. As a consequence, the learning and knowledge spillovers are captured by economic agents who will foster innovation in a territory using different approaches.

At the empirical level, there is a scarcity of literature that has focused on the territorial dimension of diversity. There is evidence of diversity on innovation at regional (Niebuhr, 2010; Dohse and Gold, 2014), and at country level (Alesina et al., 2016; Brunow and Brenzel, 2012). However, these contributions are mainly based on culture and nationality while the gender dimension has scarcely been analysed (Teruel and Quiroz, 2019). Nevertheless, most of the available academic works find that regions with higher diversity tend to out-innovate other regions. The level of endowments clearly interacts with the R&D resources available in an

TABLE 2. CLASSIFICATION OF COUNTRIES ACCORDING WITH THEIR INNOVATION ENVIRONMENT AND THEIR GENDER FRAMEWORK

	COUNTRIES BY GENDER EQUALITY			
COUNTRIES BY EUROPEAN INNOVATION SCOREBOARD	Gender equality leaders, small gender gap, more women in higher education research	Newly active countries, few women in higher education research	Newly active countries with more women in higher education research	Relatively inactive countries, some with more women in higher education research
	GROUP 1	**GROUP 2**	**GROUP 3**	**GROUP 4**
INNOVATION LEADERS	Finland Sweden Denmark	Netherlands Switzerland		Luxembourg
STRONG INNOVATORS	Norway Iceland	Austria Belgium Germany	Ireland	Israel
MODERATE INNOVATORS			Spain	Czech Republic Portugal, Malta Estonia, Cyprus, Italy, Hungary Greece, Poland, Croatia, Turkey
CATCHING-UP				Bulgaria Romania

Source: own elaboration from EC (2018) and EC (2009) economy and the productivity of these endowments increases with higher diversity.

However, some economists have pointed out that we must be cautious (Syrett and Sepulveda, 2011). Obviously, promoting innovation must be accompanied by a set of other social and economic policies. Table 2 shows this complexity by cross-tabulating the regional innovation capacity and the institutional setting in each country and policy context. Comparing the innovation classification of countries (according to the European Innovation Scoreboard classification) to their level of gender equality highlights some interesting features (Table 2).

First, countries which are well-positioned in the innovator classicationare are those which have applied actively gender equality policies. Hence, it seems that there is a positive correlation between innovation strength and the development of gender equality. Second, countries with a low innovation development are characterized by a high proportion of females in higher education research. Countries in groups (3) and (4) may indicate that there is a lower proportion of innovative private firms and that access of women to the public R&D system may be relatively equitable.

If we consider the percentage of women employed (Table 3), we see that the presence of women in the labour market has increased over time, reaching 46% in 2017. However, there are considerable variations. The greater presence of women is in the service sectors and, particularly, in the knowledge intensive services is notable, while high-tech manufacturing sectors employed a mere 26% of women. In the economic activities of generation of electricity, gas, steam and air conditioning, water supply and construction,

TABLE 3. PERCENTAGE OF WOMEN EMPLOYED IN EU-28

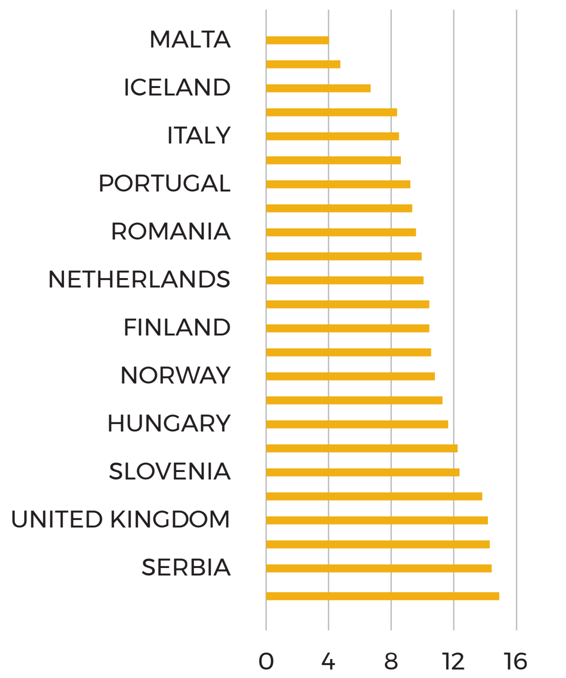
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Change 2008-2017
Total employment	44.8	45.3	45.4	45.6	45.7	45.9	45.9	45.9	45.9	46.0	1.19
High and medium-high technology manufactures	26.2	26.2	26.2	26.5	26.5	25.9	25.9	25.9	26.1	26.2	-0.07
Low and medium-low technology manufacturing	32.5	32.0	31.3	31.3	31.4	31.5	31.7	31.5	31.2	31.6	-0.89
Knowledge intensive services	58.2	58.4	58.4	58.4	58.5	58.7	58.7	58.7	58.8	58.9	0.72
Non-Knowledge intensive services	49.0	49.3	49.3	49.3	49.2	48.9	48.9	48.7	48.7	48.3	-0.68
Electricity, gas, steam and air conditioning supply; water supply and construction	10.8	10.7	10.9	11.3	11.5	12.0	11.9	11.8	11.7	12.1	1.29

Source: own elaboration from Eurostat

women account for 12.1% of employees. While this proportion is growing faster than that of total employment, its growth rate is nevertheless very modest.

Figure 1 shows the heterogenous characteristics of the percentage of women in the total workforce of each country. Overall, the underrepresentation of women in the energy and other sectors is more marked in some countries than others. National variation is considerable (between 4% and 14.5%). The countries with the highest proportion of women are Austria, UK, Lithuania and Slovenia and Switzerland (more than 12%). Those with the lowest percentages are Malta, Turkey and Iceland (less than 8%). Hence, at sectoral level, there are significant gender differences by country.

FIGURE 1. PERCENTAGE OF WOMEN IN THE ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY; WATER SUPPLY AND CONSTRUCTION AT COUNTRY LEVEL



Source: own elaboration from Eurostat

These data evidence several points of interest. First, more innovative countries are more active in the definition of gender equity policies. Second, there is a stagnation in the participation of women in the labour market. Third, participation is not homogenous at the sectoral level. Fifth, at country level, we observe a certain heterogeneity. Finally, despite there are a wide range of factors affecting innovation, the coordination of the promotion of gender equality in sectors with a low presence of women must be a key issue in order to foster innovation in the public and private sectors in order to extend creativity excellence, and benefit to society.

POLICY IMPLICATIONS

Given the persistence of gender diversity inequalities at the sectoral level, it is clear that in order to try to promote equity in the labour market is necessary address the root causes. First, in sectors such as energy, but in general in all the high-tech sectors, there is still a lack of gender diversity. This lack may erode their innovation and knowledge generation capacity. Furthermore, with the current intensification of new technologies, the gender gap among employees with IT skills will increase. This means disconnecting an important part of the labour market from the innovation process and the transformation of the sectors. The persistence of this gap requires a more comprehensive approach in policies for gender equity.

The move towards gender equality is slow and cannot be taken for granted. Hence, the persistence of these disadvantages requires a set of actions for gender equity in IT and science in the

EU in order to improve the innovation level at the firm and country levels. The following recommendations are organized by objectives which are defined as sets of actions:

Objective 1: Gender equality teams.
A goal for achieving higher productivity is to have not only a larger set of more highly qualified employers, but also a more diverse team. Diversity is required, not only for economic reasons (improving efficiency by the optimisation of human resources), but also to improve the quality of knowledge and innovation by increasing creativity and bringing science closer to society. The concept of gender diversity is also incorporated as a key element of the good management of research and innovation policies.

1. Identify the gender composition of the workforce within the different occupations. An analysis at the horizontal and vertical levels will show the capacity of each organisation to recruit and promote employees.
2. Design internal policies to recruit and promote taking into account different individual characteristics. Promotion must take into account a range of different aspects which include, among others, educational level and race. The recruitment and promotion procedure must be merit-based but searching for qualities that are complementary to the other members of the team.
3. Define measures which facilitate the promotion of both genders and erode potential barriers. The idea is to analyse potential barriers which bar promotions among current employees. The implementation of measures which facilitate work-life balance and internal mentoring may be some of strategies included.

Objective 2. Gendered innovations.
Product and service innovations are characterized by end-user acceptance. When introducing products and services, both private and public agents must take into account the particularities of final users. In order to enhance innovations and social welfare that requires overcoming gender biases in knowledge production through the mainstreaming of gender analysis in the innovation process. This objective aims to capture the needs and requirement of different users during the innovation process.

1. Identify gender biases in the development of innovations. There needs to be an analysis of whether the innovations take into account the gender characteristics of the final users. Innovations may be developed by one sex thinking primarily of final users of the same sex. Analysing whether there are gender biases will give rise to other innovations and the product will be more sensitive to individuals' characteristics.
2. Systematize the gender approach. It is necessary to take a step back and implement an innovation strategy to consider gender in the production of innovations. This action looks to define a common strategy to consider the gender dimension during the innovation process. In this sense, innovation teams must consider the differences between agents. For instance, the search procedure to elicit the requirements and needs of end users must introduce the female and male dimension in order to detect the specific requirements of each group.

Objective 3: Gender culture of innovation.

The incorporation of the gender dimension must permeate the firm's culture as a resource to stimulate creativity. This objective concerns the stimulation of the gender analysis in the search for, and assessment of, excellence.

1. Use of gender analysis as a resource to enhance scientific excellence. Designing sex and gender analysis into basic and applied research.
2. Train in gender. The innovation process must refuse the notion that increasing women's participation will automatically lead to gender-sensitive innovations. Everyone—men and women—can be trained in methods of gender analysis.

The previous measures are addressed to the firm level. However, the differences at sectoral and country level indicate that there must be complementarity among policies and agents in order to take advantage of the existing pool of innovation talent, and a cultural change in terms of challenging traditional gender roles. A crucial insight concerns the fact that, in order to progress towards a truly developed knowledge society, policies on gender diversity must be constantly implemented and adapted over time. Furthermore, they must adapt to the sectoral and country context. Cooperation between private and public agents will be necessary in order to achieve this.

REFERENCES:

Alesina, A., Harnoss, J., & Rapoport, H. (2016). “Birthplace Diversity and Economic Prosperity”. Journal of Economic Growth, 21(2), 101-138.

Amason, A. C. (1996). “Distinguishing the Effects of Functional and Dysfunctional Conflict on Strategic Decision Making”. Academy of Management Journal, 39, 123–48.

Audretsch, D., Dohse, D., & Niebuhr, A. (2010). “Cultural Diversity and Entrepreneurship. A Regional Analysis for Germany”. Annals of Regional Science, 45, 55-85.

Barabasi, A. L. (2005). “The Origin of Bursts and Heavy Tails in Human Dynamics”. Nature, 435(7039), 207.

Brunow, S., & Brenzel, H. (2012). “The Effect of a Culturally Diverse Labour Supply on Regional Income in the EU”. Empirica, 39(4), 461-485.

Campbell, K., & Mínguez-Vera, A. (2008). “Gender Diversity in the Boardroom and Firm Financial Performance”. Journal of Business Ethics, 83(3), 435-451.

Chowdbury, S. (2005). “Demographic Diversity for Building an Effective Entrepreneurial Team: Is It Important?”, Journal of Business Venturing, 20, 727-746.

Cozzens, S. E. (2004). “Gender Issues in US Science and Technology Policy: Equality of What?” in European Commission, Gender and Excellence in the Making, Office for Official Publications of the European Communities, Luxembourg, pp. 169-174.

Dohse, D., & Gold, R. (2014). “Determining the impact of cultural diversity on regional economies in Europe”, WWWforEurope working paper 58. https://www.econstor.eu/handle/10419/125710

European Commission (2009). The Gender Challenge in Research Funding. Assessing the European national scenes, Office for Official Publications of the European Communities, Luxembourg.

European Commission (2012). Meta-analysis of Gender and Science Research, Directorate-General for Research and Innovation, Brussels.

European Commission (2014). Gender Equality Policies in Public Research, Directorate-General for Research and Innovation, Brussels.

European Commission (2018). European Innovation Scoreboard (2018), Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. Luxembourg.

European Commission (2019). She Figures 2018, Directorate-General for Research and Innovation, Brussels.

Florida, R. (2002). The Rise of the Creative Class, New York: Basic Books.

Hong, L., & Page, S. (2001). “Problem Solving by Heterogeneous Agents”. Journal of Economic Theory, 97(1),123-163.

Hong, L., & Page, S. (2004). “Groups of diverse problem solvers can outperform groups of high-ability problem solvers”. Proceedings of the National Academy of Sciences of the United States of America, 101(46), 16385-16389.

Huberman, B. (1990). “The Performance of Cooperative Processes”. Physica D: Nonlinear Phenomena, 42(1), 38-47.

King, E. B., Dawson, J. F., West, M. A., Gilrane, V. L., Peddie, C. I., & Bastin, L. (2011). “Why Organizational and Community Diversity Matter: Representativeness and the Emergence of Incivility and Organizational Performance”. Academy of Management Journal, 54, 1103–1118.

Lau, D. C., & Murnighan, J. K. (1998). “Demographic Diversity and Faultlines: The Compositional Dynamics of Organizational Groups”, Academy of Management Review, 23, 325–340.

Laursen, K. (2012). “Keep Searching and You’ll Find: What Do We Know about Variety Creation through Firms’ Search Activities for Innovation?”. Industrial and Corporate Change, 21(5), 1181-1220.

Lee, N. (2015). “Migrant and Ethnic Diversity, cities and Innovation: Firm Effects or City Effects?”. Journal of Economic Geography, 15, 769-796.

Miller, T., & Triana, M.del C. (2009). “Demographic Diversity in the Boardroom: Mediators of the Board Diversity-Firm Performance Relationship”. Journal of Management Studies, 5(5), 755-786.

Niebuhr, A. (2010). “Migration and Innovation: Does Cultural Diversity Matter for Regional R&D Activity?”. Papers in Regional Science, 89, 563–585.

Nooteboom, B., Vanhaverbeke, W., Duysters, G., Gilsing, V., & Van Den Oord, A. (2007). "Optimal Cognitive Distance and Absorptive Capacity". Research Policy, 36(7), 1016-1034.

Organization for Economic Cooperation and Development (2017): The Pursuit of Gender Equality: An Uphill Battle, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264281318-en

Østergaard, C. R., Timmermans, B., & Kristinsson, K. (2011). "Does a Different View Create Something New? The Effect of Employee Diversity on Innovation". Research Policy, 40(3), 500–509.

Parrotta, P., Pozzoli, D., & Pytlikova, M. (2014). "The Nexus between Labor Diversity and Firm's Innovation". Journal of Population Economics, 27: 303- 364.

Pelled, H.L., Eisenhardt, K.M., & Xin, K.R. (1999). "Exploring the Black Box: an Analysis of Work Group Diversity, Conflict, and Performance". Administrative Science Quarterly , 44 (1), 1–28.

Romer, P. M. (1990). "Capital, labor, and productivity". Brookings papers on economic activity. Microeconomics, 337-367.

Syrett, S., & Sepulveda, L. (2011). "Realising the Diversity Dividend: Population Diversity and Urban Economic Development". Environment and Planning A, 43, 487–504.

Teruel, M., & Quiroz, P. (2019). "La Diversidad de Género: Factor de Impulso de la Innovación", Revista de Economía Industrial, forthcoming.

Thomas, D., & Ely, R. (1996). "Making differences matter". Harvard Business Review, 74(5), 79-90.

World Economic Forum (2018). The Global Gender Gap Report 2018, World Economic Forum, Geneva.

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