Plataforma para o CRESCIMENTO SUSTENTÁVEL

GAME CHANGERS

Surfing the wave of technology disruption

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COORDINATION
Platform for Sustainable Growth (PCS)

RESEARCHER | AUTHOR
António Grilo

ABOUT PCS

Jorge Moreira da Silva, *Chairman PCS*

The Plataforma para o Crescimento Sustentável (PCS)/Platform for Sustainable Growth (PCS) was launched in October 2011 as an independent, non-profit organisation, with no party affiliation. With active public participation and in coordination with national and international R&D centres and think tanks, the PCS contributes towards asserting a sustainable development model.

PCS has established partnerships with the following think tanks and foundations: BRUEGEL (Belgium), Centre for European Policy Studies-CEPS (Belgium), ASTRID (Italy), REFORM (United Kingdom), RESPUBLICA (United Kingdom), Wilfried Martens Centre for European Studies (Belgium), ENTORNO (Spain), Konrad Adenauer Foundation (Germany), FLAD (Portugal) and the Millennium Foundation (Portugal). The leaders of these institutions are members of PCS's Advisory Board, chaired by Francisco Pinto Balsemão.

PCS engages almost 400 members in Portugal – recognized leaders and experts from private sector, academia, government and NGOs – working, as volunteers, within several working groups and thematic areas.

With the publication and public discussion of the Report for Sustainable Growth, in 2012, PCS accomplished its initial mission of identifying key strategic challenges toward the growth of Portugal. After achieving this goal, PCS expanded its annual work plans to include thematic debate series and conferences, original research and policy papers in addition to our original 'crowdthinking' reports based on the ideas and contribution of PCS's members. PCS's main focus and end goal is to generate public policy ideas on the many issues addressed including, but not limited to, climate change, energy, health, education, competitiveness and growth, globalization and citizenship.

The publication *Game Changers: Surfing the wave of technology disruption* is the second in a series of in-house research projects. In-house research consists in original studies produced by visiting research fellows, who remain at PCS throughout the duration of each project.

ABOUT THE AUTHOR

Professor António Grilo is a visiting research fellow at the Plataforma para o Crescimento Sustentável (PCS) in charge of conducting the research project *Game Changers: Surfing the wave of technology disruption*.
Professor Grilo holds a PhD degree in Industrial Management from the University of Salford, UK. He is Assistant Professor with Habilitation of Industrial Engineering and Management at the Faculdade Ciências e Tecnologia da Universidade NOVA de Lisboa, Portugal, in doctoral, master and undergraduate degrees, lecturing Information Systems, Decision Models, Economics Engineering and Entrepreneurship. He is the VP of the research centre UNIDEMI (Research and Development Unit for Mechanical and Industrial Engineering).
He has over 90 papers published in scientific journals and international conferences and was the co-editor of the European Commission report *Unleashing the Potential of the European Knowledge Economy: Value Proposition for Enterprise Interoperability*, and the leading author of the book *Building Information Model and the Competitiveness of the Construction Sector*.
Professor Antonio Grilo has been working as an external evaluator and reviewer for the European Commission DG-CONNECT since 2000. He has been an expert consultant for the United Nations International Telecommunications Union (UN ITU). In the last 10 years he has been the coordinator of several international and Portuguese research and development projects in the areas of Cloud Computing, Big Data, and Artificial Intelligence applied to industrial and service sectors. He received two awards for the relevance of his research. He is a board member of the professional associations Portugal Management Institute – Portugal Chapter (PMI Portugal Chapter), and of the Instituto Português de Engenharia Industrial (IPEI). His entrepreneurial activity led him to co-found three companies.

Sumário Executivo

1. A nova vaga tecnológica

Estamos no início de uma **nova vaga tecnológica que envolve a disrupção em diversas áreas científicas**, nomeadamente, nas tecnologias de informação e comunicação, na inteligência artificial, na impressão 3D, nos veículos não tripulados, nos novos materiais, na robótica, na genómica, no armazenamento de energia, na biotecnologia e nas novas energias renováveis.

O Relatório *Game Changers - Surfing the wave of technology disruption*, resultante de um projeto de investigação da PCS, num processo liderado pelo Prof. António Grilo, parte do pressuposto de que Portugal não se pode alhear deste debate, em especial tratando-se de uma **revolução tecnológica que comporta riscos e oportunidades e que gerará vencedores e vencidos**.

O nosso Relatório procura responder a **3 questões fundamentais**:

- De que forma as tecnologias disruptivas afetarão, em Portugal, as empresas, a sociedade, os mercados, a legislação e a regulação?
- Quais as competências de que necessitamos para "surfar" de forma competente e vencedora esta vaga tecnológica, gerando crescimento e emprego?
- Quais as reformas necessárias no sistema científico, nas empresas e no Estado?

A nova vaga tecnológica, já designada, face ao seu impacto, como 4ª revolução industrial, envolve não apenas, como em todos os processos de transformação industrial ocorridos desde o século XVIII, disrupção de conceitos e de tecnologias, mas ocorre também num contexto de elevadíssima velocidade de transformação e de combinação das várias tecnologias que, dessa forma, vêm aumentado o seu impacto e potencial disruptivo.

À medida que esta vaga vai avançando, são cada vez maiores os sinais, por um lado, de **obsolescência e de falência de antigos negócios e, por outro, de nascimento e crescimento acelerado de outros negócios e empresas**. Esta revolução tecnológica coloca desafios sem precedentes a determinados modelos de negócio e ao próprio mercado de trabalho. **Os incumbentes estão em risco e os *unicórnios* multiplicam-se**.

Vale a pena ilustrar esta autêntica revolução industrial, com **exemplos de disrupção e de integração tecnológica:**

- a combinação da big data com a genómica tem condições para revolucionar os cuidados de saúde, descobrindo doenças prevalecentes em determinadas regiões;
- a utilização integrada da nanotecnologia e da genómica tem o potencial de desenvolver novos fármacos para o cancro;
- equipamentos de nanotecnologia, ajustados à dimensão das moléculas, podem ser usados para criar sensores associados a tecnologias móveis, criando novas aplicações da "internet das coisas";
- a integração das tecnologias de informação e comunicação com os equipamentos de produção, consumo e de contagem de energia, permite desenvolver as smart grids, o autoconsumo a partir de fontes renováveis e a eficiência energética. Não só o cidadão se tornará, cada vez mais, produtor da sua energia, como os seus equipamentos de consumo comunicarão entre si, de modo a reduzir o consumo de energia;
- a combinação da inteligência artificial com as tecnologias de informação e de comunicação permitem o desenvolvimento de veículos conduzidos automaticamente com benefícios muito significativos não apenas em termos de emissões mas também na segurança das pessoas e, muito particularmente, na mobilidade dos idosos.

As estimativas quanto aos **benefícios económicos, anuais, até 2025**, da disrupção tecnológica são eloquentes:

computação na nuvem	**€6.2 biliões**
internet móvel	**€10.8 biliões**
inteligência artificial	**€6.7 biliões**
"internet das coisas"*	**€6.2 biliões**
big data	**€1.1 biliões**
impressão 3D	**€550 mil milhões**
veículos autónomos	**€1.9 biliões**
novos robots	**€4.7 biliões**
genómica**	**€1.6 biliões**
aplicações da nanotecnologia e dos novos materiais na medicina	**€500 mil milhões**
armazenamento de energia	**€635 mil milhões**
tecnologias limpas, energias renováveis e redes de energia	**€2 biliões**

* generalização dos sensores

** em especial, os desenvolvimentos ao nível da sequenciação, da modificação genética e da análise big data

Esta nova vaga do conhecimento tem vindo a gerar **ganhos de produtividade na economia e a melhorar a vida de milhões de cidadãos.** No entanto, tem vindo também a **gerar dilemas e dúvidas quanto às questões de privacidade e de confiança**. A circunstância dos grandes computadores e das infraestruturas digitais estarem cada vez mais integradas com as infraestruturas e sistemas físicos, comandando-as, gera novos receios quanto aos ciber-ataques e seus potenciais efeitos negativos nas infraestruturas críticas, como centrais e redes de energia, redes de telecomunicações, aeroportos, hospitais e transportes. O mesmo tipo de dilema se coloca com a enorme simplificação do processo de sequenciação genética, com recurso a computadores cada vez mais próximos daqueles que utilizamos no nosso dia-a-dia.

Logo, não está apenas em causa perceber as implicações da revolução tecnológica na economia e nos mercados. A nossa análise tem também de incidir sobre as implicações na sociedade e nos mecanismos de regulação.

2. Os desafios colocados a Portugal

Deixar andar e aguardar é a pior das opções para as empresas, mas também para os cidadãos, para os governos e para os reguladores. **Temos de preparar Portugal para esta revolução tecnológica.**

Enfrentar os riscos de obsolescência, desajustamento e inviabilidade, na economia e no mercado de trabalho, causados pela presente revolução tecnológica, representa, mais do que uma inevitabilidade, uma oportunidade que deve ser abraçada com ousadia, abertura, inovação e empreendedorismo. **O que faz deste desafio um *game changer* são as pessoas e não as tecnologias.**

A nova vaga tecnológica gerará **novos desafios aos incumbentes e contribuirá para a entrada de novos empreendedores**. Assim, no caso português, alguns dos sectores mais dinâmicos na exportação – veículos automóveis, refinação, plásticos, maquinaria e equipamento, *utilities* da área da energia e operadores de rede – enfrentarão grandes desafios nos próximos 5 a 10 anos. Estes desafios configuram riscos mas também significativas oportunidades de competitividade e de internacionalização. Mas não se trata, contudo, de algo totalmente novo. Verifique-se o ocorrido no setor têxtil nacional, que ultrapassou, há mais de 10 anos, os impactos da globalização, através da aposta no design, nos novos materiais *(nanofabrics)* e na robótica.

Paralelamente, a disrupção tecnológica abrirá novas oportunidades ao surgimento e crescimento de start-ups de base tecnológica. Disso são já exemplo as várias empresas inovadoras criadas por empreendedores portugueses, como a Veniam (internet das coisas aplicada à mobilidade sustentável e à monitorização ambiental), Feedzai (inteligência artificial), Unbabel (inteligência artificial), Talkdesk (aplicações da computação na nuvem a contact centres), Farfech (comércio eletrónico), BeeVeryCreative (impressão 3D), LineHealth (aplicações da computação móvel ao setor da saúde), Coimbra Genomics (sequenciação genética).

A nova vaga tecnológica coloca assim um desafio central, tanto a incumbentes como aos novos empreendedores: a **rápida adaptação às novas tecnologias**, capturando as vantagens associadas à atitude de pioneiro, nomeadamente, redução de custos, desenvolvimento de novos produtos e rápida entrada em mercado. Nesta transformação mundial, **queremos seguir ou queremos liderar?**

Não basta uma rápida adaptação do setor empresarial. Para que Portugal possa competir e vencer no contexto desta nova vaga tecnológica é **fundamental uma abordagem mais ambiciosa na área da educação e da investigação.** É verdade que, nos últimos anos, se registaram melhorias na redução do abandono escolar (de 27% para 13% nos últimos 4 anos); nos indicadores PISA sobre competências dos alunos do ensino secundário; na avaliação do ensino de ciências e tecnologias; no reconhecimento internacional quanto ao desempenho dos nossos doutorados e dos nossos cientistas. Mas não é menos verdade que **a nossa capacidade de "surfar" a nova vaga tecnológica depende de um grande salto quantitativo e qualitativo, nos próximos anos, na área do conhecimento**, traduzido numa redução ainda mais drástica dos níveis de abandono escolar; no aumento do número de licenciados, mestres e doutorados; na melhoria das competências dos jovens na matemática, leitura e ciências; num maior investimento privado em ciência; e no rápido aumento do número de patentes e de produtos resultantes de atividades de I&D.

3. Recomendações Game Changers

O Relatório formula 3 recomendações fundamentais para que Portugal se possa preparar para a nova revolução tecnológica:

1. UM PACTO EDUCATIVO PARA AS COMPETÊNCIAS TECNOLÓGICAS E PARA A DIGITALIZAÇÃO:

- É fundamental estabelecer um pacto educativo – ambicioso, estável e previsível – visando o **desenvolvimento de competências dos alunos nas novas áreas tecnológicas, num contexto letivo interdisciplinar**, combinando rigor científico e académico com criatividade e empreendedorismo, resultando da parceria entre academia, empresas incumbentes e *start-ups*.
- Este Pacto deve fomentar o desenvolvimento de **novos talentos na "classe de criadores"** (*Creative Class*, segundo Richard Florida), nas áreas da ciência, engenharia, programação, artes, design, media, educação, saúde, finanças, gestão e direito.
- O sistema educativo deve contribuir, ainda, para o **desenvolvimento das competências de toda a sociedade na área digital**, em especial, ao nível da reconversão e atualização dos trabalhadores dos setores da indústria e dos serviços.

2. UMA REDE DE ECOSSISTEMAS DE INOVAÇÃO:

- Mais do que adotar uma estratégia caracterizada pela lógica do "cada um por si" ou pela perspetiva ilusória de que um país da dimensão de Portugal se pode afirmar internacionalmente adotando abordagens de economia de escala (e não de economia de rede), temos de desenvolver **novos *clusters* tecnológicos a partir de verdadeiros ecossistemas de inovação** que agreguem, sob a mesma estratégia de colaboração, inovação e internacionalização, **grandes empresas, *start-ups*, universidades e institutos politécnicos**.
- Estes ecossistemas regionais e nacionais devem ser **incubados e liderados por "campeões tecnológicos"**, de preferência do setor privado. A dinamização destes ecossistemas terá de envolver programas de aceleração, plataformas digitais de *open innovation*, projetos de investigação, ações de capacitação e formação de quadros, estratégias de atração de capital de risco e internacionalização.

3. POLÍTICAS E REGULAÇÃO AO SERVIÇO DO EMPREENDEDORISMO E DA INOVAÇÃO:

- Portugal tem de se posicionar como um **país de atração de talentos, de projetos e de investimento** associados a esta vaga tecnológica. Para isso, é indispensável desenvolver políticas e mecanismos de regulação que traduzam o objetivo de fazermos do **empreendedorismo, da inovação e da abertura à mudança, competências transversais a todos o setores e cidadãos, e não apenas das novas empresas**. Em especial, porque o que faz deste desafio um *game changer* são as pessoas e não as tecnologias.
- É fundamental remover as barreiras regulamentares e administrativas à **digitalização da economia**, desenvolver políticas públicas de fomento de **novas empresas tecnológicas e promover a atração** para o território nacional de iniciativas, empresas e projetos internacionais.
- A **administração pública deve liderar pelo exemplo**, não só ao nível da utilização de tecnologias de dados abertos *(open data)* no relacionamento do Estado com as empresas e com os cidadãos, mas também da adoção de estratégias de digitalização de todos os processos internos e dos serviços prestados, tendo sempre em atenção a necessidade de acautelar o apoio aos cidadãos com menores competências na economia digital.

Neste contexto de profunda e acelerada rutura tecnológica, que está a transformar a economia, os mercados e o trabalho, não basta apenas reagirmos e adaptarmo-nos. Portugal pode e deve agarrar esta revolução, antecipando as novas tendências e liderando as oportunidades que estas já estão a criar.

O Relatório da PCS Game Changers - Surfing the Wave of Technology Disruption pretende contribuir para esse processo, identificando os impactos e oportunidades, que esta vaga tecnológica pode representar para Portugal e lançando um conjunto de recomendações de políticas públicas e de opções empresariais que respondam às necessidades dos mercados e profissões do futuro e que sejam potenciadoras de novas competências e de novos clusters de crescimento no nosso país.

We are on the brink of a new technological wave, which no one knows how to ride.
This technological wave, yet impossible to fully understand, spans many scientific domains: digital, artificial intelligence, additive manufacturing, robotics, genomics, Energy Storage, or Renewable Energy. The forthcoming technological disruption is likely to lead to a "creative destruction" on a scale never seen before, with new companies and business models emerging and shaking incumbents.
Still, this technological disruption is rarely seen as relevant by corporate board-level in most of large size companies.

Game Changers - Surfing the wave of technology disruption aims to draw attention to the challenges posed by the new technological wave, particularly in light of Portugal's reality and environment. It builds upon much of the work previously done by various experts, offering a meta-analysis of the main data and conclusions drawn so far, while looking at the Portuguese economy and societal reality. The report reviews the main technologies, which are organized in five main groups: Digital; Robotics; Genomics; Advanced Materials; and Energy. It looks at how technologies will transform companies and society, the technology and market maturity, expected impact on economy and jobs, legislation and regulation issues, and main enablers and hindrances. The report sheds light on how Portugal's talents must face forward to grip the opportunities brought by the technology wave while highlighting the need to create the right economic and societal environment for people's talents to emerge.

Our research concludes with three main recommendations that should guide policy makers. **First**, we propose setting up an educational contract for the technological wave and promote an educational system that, at different levels, focuses on talent development for the creative class. This educational system must move away from traditional silo-based scientific domains and rather favor cross-fertilization across areas combining scientific academic rigor with practitioners' experiences and knowledge base. **Second**, government must design policy for supporting the emergence of more numerous and larger technology-based ecosystems. We must provide incentives to national and international technology-based companies to move their operations and services to Portugal. A prime lever of this policy must be the development of a network of national, regional and local technology leaders that act as role models for the ecosystems. **Finally**, Portugal must design technology-friendly policies and regulations, while developing a widespread reputation of an entrepreneurial society and economy that nurtures innovation and embraces change. This movement, in turn, will potentially create new jobs grounded on the creative class and encourage entrepreneurs to scale up their successful businesses in Portugal.

1. Is this Technology Wave for real?

Nazaré Canyon Wave. For many years, surfers didn't know if the big waves in Nazaré were surfable. In 2005, a young body-boarder called Dino Casimiro bought a digital camera, took pictures of the most impressive waves at Praia do Norte and sent one to Garrett McNamara, whom he knew only from the Internet. It wasn't until 2011 that it caught people's attention when Garret McNamara made it to the Guinness Book of World Records by surfing the biggest wave in history. Surf has never been the same since then. Neither has Nazaré.

We are on the brink of a new, and unpredictable, technological wave, which no one knows how to ride. This Technological Wave, or T-Wave spans several scientific domains: digital, artificial intelligence, additive manufacturing, robotics, genomics, Energy Storage or Renewable Energy. The upcoming Technological Wave differs substantially from previous ones due to a combination of factors but, primarily, because it unfolds at an unprecedented speed. Innovation is extremely fast, new products and services rapidly gain traction as incumbents try to figure out how to adapt from traditional business models. The forthcoming T-Wave disruption is likely to lead to a creative destruction on a scale never seen before, with new companies emerging, leading to major market shifts in increasingly shorter timespans. Everyday we see evidence of this Technological Wave coming.

As technologies evolve, they are likely to be combined in many different ways, reinforcing each other's potential and reaching greater impact. For example, the combination of Big Data with genomics has the potential to revolutionize public healthcare by uncovering diseases that prevail in localized geographical areas. Nano-technology devices, the size of molecules, can be used in the deployment of sensor-like devices and be combined with mobile applications, thus creating a new scope for Internet of Things technologies. Genomics combinations with Big Data and Cognitive Computing are likely to achieve dramatic advances in healthcare.
This T-Wave creates great potential to improve the lives of billions of people. Digital technologies, for example, are increasing productivity and quality in many disparate sectors like education, healthcare, transportation or public services.
At the same time, there are potential downside effects and rising risks of security and privacy breaches, compromising trust on deployed systems.
As machines, applications, and digital infrastructure become seamlessly interconnected with physical systems, its hacking risks increase as well, creating unimaginable threats to economic assets like factories, airports, railways, networks, power plants, etc. Progress of genomics research has the potential to trick our biology but, if misused, it can lead to disastrous effects. Low-cost desktop gene-sequencing machines may not only put the power of genomics in doctor offices, but also potentially in the hands of terrorists. Hence, beyond understanding the technology, the business and market impacts, we must be aware of the lateral

implications related to the deployment of innovative services and products, while working to minimize the risks and to guarantee its responsible and safe usage.

Yet, astonishingly, this technological disruption is not seen as relevant for corporate board-level in most of large size companies. Most companies either do not acknowledge the risk of technological disruption, or have not addressed it sufficiently **[8]**. There is a significant risk that many companies run out of business due to their inability to cope with changing business models and technology. For instance, there are plenty of examples of companies from the digital ecosystems entering into once traditional business areas and changing the dynamics of the industry. The recent polemics around UBER and Airbnb are just some of the examples of how digital companies created market disruption in the transportation and hospitality sectors. Still, most corporations are taking a "wait and see" approach. So are governments, in general.

It is not just companies that need to learn how to "surf" the Technology Wave – T-Surf. Policy makers and societies need to prepare for the T-Wave as well, by understanding the impact of emerging technologies on competitive dynamics and on the economy as a whole. They must be aware of how these phenomena will transform the configuration of jobs, particularly highly skilled professions, as well as the employment in general. Governments, policy makers, and regulators need to envisage the right environment for people and society to cope with the coming disruption. We must work collectively towards enabling people to grow with the emerging opportunities as opposed to making them feel alienated. The technology disruption will bring major privacy, security and trust societal issues challenging policy legislators and private entities to identify comprehensive and adequate solutions. Indeed, governments will need to improve cooperation mechanisms with these private entities, since coping with risks must imply the public and private sectors working together.

Finally, people must also look at this wave as an opportunity rather than a doomsday. Change will come with people. Young or old must have an entrepreneurial attitude towards the upcoming challenges. In all big disruptive movements there are always incredible opportunities taken by those who are willing to take risks and evolve. What makes this a game changer are the people, not the technology *per se*. Technology is a lever, but it is people who should be steering the change.

In the last three years, a set of reports and books have been written by leading experts in the field of technology and innovation, calling out for the mobilisation of corporations and policy makers in the wake of disruptive change. Erik Brynjolfsson and Andrew McAfee, from MIT, wrote in 2014 *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies,* which focuses on the impact of digital, artificial intelligence and robotics technologies. In the book *No Ordinary Disruption: The Four Global Forces Breaking All the Trends*, Richard Dobbs and James Manyika, from the Mckinsey Global Institute, offered, in 2015, an in-depth analysis of how a confluence of disruptive forces are reshaping the world and producing significant change to economy and society. Namely: the rise of emerging markets, the accelerating impact of technology on the natural forces of

market competition, an aging world population, and accelerating flows of trade, capital and people. The same authors, in a MGI team, had previously written, in 2013, the report *Disruptive technologies: Advances that will transform life, business, and the global economy,* tackling mainly the technology dimension.
More recently, two other reports have provoked some stir. *Digital Vortex: How Digital Disruption Is Redefining Industries*, by authors of the IMD and the Cisco Initiative, stresses that 40% of major market players may be out of business in the foreseeable future. The authors emphasized that most executives are not yet aware of the threats and opportunities posed by the technological wave. Also, The Boston Consulting Group's report *Man and Machine in Industry 4.0 – How will technology transform the Industrial Workforce through 2025?*, though focusing on the industrial sector, offers an insight into the expected impact on employment and jobs.
Many other sectorial or technology-based reports have been recently written, claiming the need for setting the scene for change.

Just recently, the World Economic Forum's (WEF) annual meeting, held in Davos, on January 2016, was dedicated to the "The Fourth Industrial Revolution". The official topic was the subject of an ongoing WEF initiative and of the WEF Report released in anticipation of the Davos Meeting, *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution.* It aimed to serve as a call to action and to enhance the current stock of knowledge on anticipated skill needs, recruitment patterns and occupational requirements. However, most of the news coverage of the Davos meeting placed too much emphasis on the negative impacts of this industrial revolution, rather than on the opportunities it presents and the need for change. More recently, in April 2016, the European Commission (EC) launched the first industry-related initiative of the Digital Single Market package, *Digitising European Industry: Reaping the full benefits of a Digital Single Market*, embracing the challenge to turn the 4th Industrial Revolution to Europe's advantage. The purpose of this Communication is to reinforce the EU's competitiveness in digital technologies and to ensure that every industry in Europe, in whichever sector, wherever situated, and no matter of what size, can fully benefit from digital innovations.

This report, *Game Changers – Surfing the wave of technology disruption,* aims to draw attention to the challenges posed by the new technological wave, particularly in light of Portugal's reality and environment. We draw upon much of the work previously done by various experts, and offer a meta-analysis of the main data and conclusions drawn so far, while looking at the Portuguese economy and societal specificities.
We can't know if the future will be as we foresee, but we understand that things will never be the same again. If we want to take advantage of the big wave, we better start learning how to surf it.

The report is organized as follows. In **section two**, we describe the main technologies that are expected to have a significant impact. The technologies are organized in five main groups: Digital; Robotics; Genomics; Advanced Materials; and Energy. Within the Digital, six subcategories are considered: Cloud Computing, Mobile Computing, Cognitive Computing, Internet of Things, Big Data, Additive Manufacturing/3D Printing. In the Robotics, there are two subcategories considered: Autonomous

Vehicles and Advanced Robots. In the Energy category, we considered two subcategories: New Energy Storage and Renewable Energy. Each of the categories/ subcategories is analysed from the following angles: Its Features; How It Will Transform Companies and Society; Technology and Market Maturity; Expected Impact on Economy and Jobs; Legislation and Regulation Issues; and Enablers and Hindrances.

Section three analyses how the technological wave is likely to impact Portugal's economic sectors in general, and whether incumbent companies and startups are prepared to deal with the opportunities. This section also looks at how Portugal's talents must evolve in the face of the T-Wave and how to create the right economic and societal environment for people's talents to emerge.

Section four is about learning how to surf the technological wave, from an institutional perspective. It draws attention to the need to change education and educators, the importance of nurturing technology-based ecosystems and creating a network of role models. In addition, it emphasizes the need to drive policy makers and legislators to swiftly adapt to the rapid technological innovations, and looks at how data-based approaches can help both supervise governmental decisions and trigger innovation and entrepreneurship.

Finally, in **section five**, a set of 3 major public policy recommendations are put forth, seeking to bring Portugal's economy and society to the frontlines of coping with the T-Wave.

This report suggests that Portuguese economy and society should surf the T-Wave, while capitalizing on the best that our 870 years old culture and society have to offer. A good example of the desired technological revolution in Portugal, where old meets new, is the conversion of the old Mercado da Ribeira in Lisbon to the Mercado da Ribeira *Time Out*. An old but iconic space used for traditional grocery, Lisbon's main food market since 1892, now coexists with a new fashionable space, where Portugal's main gourmet chefs and restaurants offer the most sophisticated food. In the past two years, the traditional market has been transformed into a very popular and trendy area, while preserving its original and historic character. Traditional skills have been added to creative talents and the space has reborn, lively and full of tourists. In addition, it is also home to the largest co-working space for high-tech startups in Lisbon.
Another good example of innovation arising from established traditions is the way modern day Fado music has reinvented itself with artists like Mariza, Ana Moura, Carminho or Camané (to name a few). These singers have adapted and adopted other tones, other music instruments (like keyboards, piano, electric guitar, drums, etc.), and turned this traditional Portuguese music genre into an international beacon of creativity.

In short, this is the strategy we should be aiming for Portugal: promoting innovation and entrepreneurial activity rooted in traditional distinctive elements and emergent economic sectors while leveraging disruptive technologies and our competitive advantage in the global arena.

2. Disruptive Technologies

This section describes the technologies that are creating, or will create in the foreseeable future, disruption in the markets. The goal is to describe the characteristics of the technologies and their potential impact. This assessment is based on the meta-analysis of the various technical reports analysed.

2.1 DIGITAL

2.1.1. Cloud Computing

Features

Cloud Computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction **[1]**. The main characteristics of this technology are summarized in **Table 1**.

How It Will Transform Companies and Society

Cloud computing has a definitive role at large organisations. **Table 2** shows some examples of application in different business domain **[79, 1, 4, 7]**.

Table 1 Characteristics of cloud computing

CHARACTERISTICS	DESCRIPTION
On-demand self-service	A consumer can unilaterally provision computing capabilities as needed automatically without requiring human interaction with each service provider.
Broad network access	Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms.
Resource pooling	The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand.
Rapid elasticity	Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward with demand.
Measured service	Cloud systems automatically control and optimise resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service.

Table 2 Examples of application of cloud computing

EXAMPLE OF APPLICATION	DESCRIPTION
Aerospace and defence industry	A collaboration platform to manage the complex task of exchanging product and production data among multiple partners.
Internet-based services	Online searching – Social networks – Streaming media – Offline storage of personal data – Pay-as-you-go models for consuming IT
Industry	Companies in a cooperative industrial network can use this technology to collaborate on a global scale.
Healthcare	Patient data and health histories are being made available through cloud providers.
Pharmaceutical industry	Pharmaceutical companies have explored ways to fundamentally reshape their processes for discovering new drugs by using cloud computing.
Media industry	Competitors, such as television networks or cable channels, can agree to operate common content production, distribution, and storage platforms in order to create a radically lower cost basis.

Cloud technology has also the potential to transform the companies by centralizing computers, storage, and applications on the cloud, raising IT productivity by increasing utilisation and reducing the number of employees needed to maintain systems and develop software.

As a core enabler of the Internet, cloud computing could have a tremendous impact on consumers' lives. The surplus generated by the Internet could be valued in trillions of dollars by 2025 **[3, 7]**. The proliferation and sophistication of cloud services could be a boon to entrepreneurs and small enterprises as cloud platforms make it much easier and cheaper for small businesses to pay for IT resources on a per-use basis, allowing them to scale their IT capacity up or down and build critical operational capabilities. Consumers will likely continue to benefit as new cloud-enabled apps and services emerge and reduce the need to install and maintain local applications **[2, 3]**.

Technology and Market Maturity

Regarding the technology development stage, companies are already using cloud-based software for some enterprise and analytics applications, but with the increasing use of applications and sensor-based computing, more production-related undertakings will require increased data sharing across sites and company boundaries. At the same time, the performance of cloud technologies will improve, achieving reaction times of just several milliseconds **[2]**. Although many businesses are using this technology, its market development stage is not yet mature. However, by 2025, most IT and Web applications and services could be cloud-delivered or enabled, and most businesses could be using cloud facilities and services for their computing resources **[7]**.

Expected Impact on Economy and Jobs

The total economic impact of cloud technology could be €1.7 trillion to €6.2 trillion annually in 2025 **[3]**. Most of this impact (€1.2 trillion to €5.5 trillion) could be in the form of additional surplus generated from cloud delivery of services and applications to Internet users, while €500 billion to €700 billion could come through productivity improvements for enterprise IT.

Regarding the expected impact on jobs and employment, the European Commission estimates that cloud computing and app economy will create an additional 3 million jobs in Europe by 2020 **[2]**.

Legislation and Regulation Issues

Although the cloud technology has great potential to improve the lives of billions of people and the performance of companies throughout the world, there are some unwanted side effects and issues that must be addressed by public bodies or decision-makers. For example, as cloud technology enables Internet-based delivery of more and more applications and services, policy makers will be under pressure to update laws relating to data ownership and privacy as they relate to the cloud **[11]**. In addition, data protection laws in many countries restrict the storage and transfer of several types of data outside their borders, which constrains the ability to take advantage of some of the benefits of cloud technology.

Enablers and Hindrances

An enabler to the evolution of the cloud technology is the network capacity, especially wireless networks for consumers using the mobile Internet **[4]**. Conversely, trust is a major hindrance that cloud computing is facing as its more widespread use requires a level of trust that some managers and consumers are reluctant to grant **[4]**. Many consumers still prefer to store their data on PC hard disks instead of trusting the cloud as a permanent and secure repository for their photos, personal records, and other irreplaceable material. Enterprises, too, continue to have concerns about placing sensitive data on a third-party cloud, especially as questions of ownership and liability for data residing in a particular online location have yet to be settled by policy makers **[7]**. Another hindrance is the complexity of migrating enterprise IT systems with multiple platforms, network protocols, and programming environments to the cloud.

How Cloud Computing is entering in everyone's life

Applications for daily work

The use of Gmail, Google Docs or Google Drive is a perfect example of how cloud computing is becoming widely present in our personal and professional lives. These applications were designed to provide access to users of the traditional local desktop applications through the Web, meaning that rather than having to install it in the local hard disk, users need only to have an Internet connection (though they also allow use offline). This enables also a different business model, as corporate users rather than paying the suite as a product, at the time of the purchase, they can pay a service, being charged as much (time) as they use it. This technology/business model is called Software as a Service (SaaS).

Disruptive change in healthcare

The Electronic Health Record (EHR) is a digital record of patient health information. It contains all the information traditionally found in doctors' paper charts. EHRs include past medical history, vital signs, progress notes, diagnoses, medications, immunisation dates, allergies, lab data and imaging reports. They can also contain other relevant information, such as insurance information, demographic data, and even data imported from personal wellness devices. The enabling capability EHR lies not only in the data it contains, but how it is shared. EHRs makes health information instantly accessible to authorized providers across practices and health organisations, helping to inform clinical decisions and coordinate care. With cloud-based EHR, patient data can be shared with all clinicians and organisations involved in a patient's care such as labs, specialists, imaging facilities, pharmacies, emergency facilities, and school and workplace clinics, depending on access being granted to health agents, with them **[3, 7]**. There are several Portuguese companies like Alert Life Science Computing or MedicineOne that have been internationally successful in developing and selling this type of service. The new generation of these applications is to predict and anticipate patients' needs by using the data collected from innovations like portable devices for monitoring patients' health, so that providers can deliver more personalized services and improve the quality of care **[80]**. By mining and analyzing clinical databases, healthcare analytics can help researchers and healthcare providers make analytics-based diagnoses and decisions.

Changing Payment and Money Transfer

Bitcoin is now a game changer in digital payments and money transfer systems. Although it is not a typical cloud computing application, it is grounded on services that are totally dematerialized and that only exist in the Internet. Bitcoin can be used to pay for goods and services without a third-party broker, like a bank or government. The currency emerged seeking to overtake the central bankers and governments who usually

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control the flow of currency, and Bitcoin became both a digital currency and a payment system **[11]**. While, initially, Bitcoin was exclusively used to buy digital products and services, it recently started to be used to buy traditional products, as well, such as Tesla cars. One of the advantages of Bitcoin is that it can be used without paying a fee to the credit card industry, and thus these costs can be dramatically reduced when customers shop via Bitcoin, since the transactions are being processed not by traditional banking institutions but by some competing computers. Bitcoin can also be used by people in developing countries, who might have cellphones but not bank accounts, since all they have to do is install an application on their mobile phones or computers, and then purchase goods or services from a Bitcoin exchange. Also, Bitcoin payments can be anonymous to some extent, which could be a selling point to people who are concerned about privacy or taxation issues. This later advantage is also a major reason why regulators and governments want to disable Bitcoin, since it has become the currency for much of the criminal activity occurring throughout the Internet, namely on the Darkweb **[6]**.

2.1.2 Mobile Computing

Features

Mobile computing refers to a combination of mobile computing devices, high-speed wireless connectivity, and applications **[3]**. The technology has applications, beyond traditional consumer use of smartphones for basic communication and entertainment functions, providing companies and organisations in general with more efficient ways to deliver services and creating opportunities to increase management and workforce productivity. Mobile computing is about transforming services traditionally delivered using computer-based devices (desktops or notebooks), to handheld devices like smartphones, tablets or other devices that imply a significant change in the way personal and business applications, processes and information are stored, accessed and processed **[3, 7]**.

How It Will Transform Companies and Society

Mobile computing has a great potential to transform companies, as the technology could have considerable impact on improving internal operations, from frontline workers to sales workforce or highly paid knowledge workers. Workers can use mobile Internet technologies to enable communications and collaboration, which could raise interaction and worker productivity by 20 to 25%, particularly by reducing the time it takes to handle email, search for information, and collaboration with colleagues **[3, 7, 55]**. The estimated potential economic impact of worker productivity gains achieved via the use of mobile Internet applications in internal operations could be €1.0 trillion to €1.7 trillion annually, by 2025 **[3].**

As mobile Internet offers valuable services to citizens, the society is also being affected by this technology **[3, 55]**. The mobile Internet could affect how five billion people go about their lives, giving them tools to become potential innovators or entrepreneurs **[3, 7, 55]**. For example, entrepreneurs in developing economies might be able to compete globally in online commerce, while global players will have a new channel to reach the fastest-growing markets **[55]**.

Technology and Market Maturity

In terms of the technology development stage, the full potential of the mobile computing is not yet realized, as mobile computing devices (e.g. smartphones and tablets) and applications are evolving every day. In the coming years, mobile Internet devices will be much smaller, more wearable, and combined with Internet of Things technologies. We are witnessing startups and SME becoming mobile leaders in emerging markets, leapfrogging older generations of technology providers still widely used in developed markets **[4, 55]**. The share of mobile leaders in countries like China, Brazil or India exceeds that in the developed countries **[55]**.

By 2016, developing economy markets are expected to be the largest source of smartphone market growth. The worldwide mobile phone market will reach a total of 1,928 million unit shipments in 2015, down 1.7% from the 1,961 million units shipped in 2014 **[5]**. Continued reductions in the prices of smartphones and data plans should help to sustain rapid adoption rates.

Expected Impact on Economy and Jobs

Mobile Internet could generate annual economic impact of €3.7 trillion to €10.8 trillion globally by 2025 **[3, 7]**. This value would come from three main sources: improved delivery of services, productivity increases in select work categories, and the value from Internet use for the new Internet users who are likely to be added in 2025.
The mobile Internet has great potential to improve delivery and raise productivity mainly in healthcare, education, and other public and social services **[3, 4, 7]**. Healthcare is one of the most promising, with an estimated impact of €900 billion to €2.1 trillion per year, by 2025 **[3]**. In education, mobile computing could have an economic impact of €300 billion to €1 trillion annually **[3]**. In the public sector, the potential economic impact of delivering government services using mobile Internet technology could reach €200 billion to €500 billion per year, by 2025 **[3, 5, 55]**. In the retail sector, mobile Internet usage could have a potential economic impact of €100 billion to €400 billion per year **[3]**.

In developing economies, governments have much to gain from mobile Internet usage as a driver of development and employment **[55]**. As it has been done in other places, the shift of business to the Internet can be disruptive to employment. However, for every job that is lost due to the Internet in small and medium-size enterprises, survey data indicates that in some developing countries millions of new jobs could be created as well.

Legislation and Regulation Issues

Mobile computing poses rising risks of security. For instance, objects and machines under the control of computers across the Web can be hacked, exposing factories, refineries, supply chains, power plants, and transportation networks to new risks **[6]**. It also raises serious security and privacy breaches issues as the growing focus of computer hacking has been on mobile technology **[6]**. Although there are serious issues of security and privacy, policy makers and private entities (hardware, software, network carriers, service providers) will have to work together to find feasible and balanced solutions that provide protection and provide users with control of their data, and still enable the development of innovative mobile computing tools and services.

Enablers and Hindrances

There are also enablers and hindrances to the evolution of the technology. For example, progress in battery technology will be needed in order to bring mobile Internet access to places in the developing world that lack a reliable supply of electricity. Also, creating the infrastructure to increase global high-speed Internet coverage will require significant capital expenditure. Moreover, the economic potential of mobile Internet usage may not be fully realized if sufficient wireless spectrum capacity cannot be made available **[4]**.

For incumbent Internet businesses, growing mobile Internet use poses multiple challenges. To remain competitive, they must adapt their services to mobile networks, often requiring significant investment. For many businesses, the prospect of up to three billion more consumers coming into the digital economy could require fresh thinking and new approaches **[7]**. Business leaders will have to learn how to please these new consumers and effectively meet their needs. Policy makers around the world must learn how to use mobile Internet access to improve services, increase productivity, and drive economic development. Governments can also play a crucial role in accelerating the adoption of mobile Internet access by funding basic research and helping to overcome major barriers, for example by allocating scarce spectrum.

Transforming people's transportation with UBER

Mobile computing is introducing significant changes and is promoting new modes of transport: renting fractions of a Zipcar's time; using Avego to share rides with strangers or GoLoco to share them with friends; using peer-to-peer car sharing services like RelayRides or Getaround, and new on-demand car services like UBER.

The most successful case is UBER, a startup company connecting passengers with drivers of vehicles (normal or luxury). By using mobile technology to create a convenient and efficient reservation and payment service, UBER has created a robust market. Its success among consumers has expanded the demand for drivers who, with the aid of a smartphone and app, now have greater opportunities than those offered by working solely for a conventional taxi service. Currently, there are about 200,000 drivers worldwide, in several different categories. UBER was founded in 2009 and has reached a €47 billion valuation, in under six years, making it perhaps the fastest-growing company in world history.

An important feature of UBER service is that both passengers and drivers are rated after each trip on a scale from 1 to 5. Drivers getting low ratings, face the risk of being deactivated and out of service. Likewise, passengers rated poorly risk not getting a car when requesting one. The app has also a report feature and if something is reported, the local management receives an alert. This ensures that drivers have a clean car, behave professionally and don't take inefficient routes to the destination.

UBER has recently faced pressure from local regulators, arising from tensions with taxicab service. In Portugal, the courts have accepted a provisional ruling for inhibiting the service, though it remains operational because the overall system is global and conducted over the Internet, thus hard to stop.

2.1.3 Cognitive Computing

Features

Cognitive computing can be defined as the use of computers to perform tasks that rely on complex analyses, subtle judgments, and creative problem solving, i.e. intelligent software systems that can perform knowledge work tasks involving unstructured commands and subtle judgments **[4]**.

One of the main characteristics of this technology is the ability to create new relationships between knowledge workers and machines **[4, 7]**. Sophisticated analytics tools can be used to augment the talents of highly skilled employees, and as more knowledge worker tasks can be done by machine, it is also possible that some types of jobs could become fully automated **[7, 16]**. With advanced interfaces and artificial intelligence software, computers can understand and interpret human speech, actions, and even intentions from ambiguous commands. In short, computers can increasingly do many of the tasks that are currently performed by knowledge workers **[3, 4]**. This trend is not new, as in the past many jobs have disappeared with the use of the technology. The main distinctive challenge of current technology disruption is the type of jobs that are now being replaced, as technology is enabling automation of knowledge intensive jobs. However, this should not be seen as a menace but rather as an opportunity. As History has proven time and again, technology has always led to the creation of new jobs that required specific human skills, unthought-of until the need emerged with the deployment of the new technology.

This technology has a wide range of applicability. **Table 3** illustrates a sample of its examples of application **[3, 4, 7, 16]**.

Table 3 **Examples of application of mobile computing [3]**

EXAMPLE OF APPLICATION	DESCRIPTION
Marketing	A manager or executive could simply ask a computer to provide the information on the performance of a certain product in a specific market.
Technical professionals	To use deep learning techniques to discover new relationships in huge amounts of data, and to determine which relationships are the most important, amounts to an enormous shortcut in many kinds of technical work.
Healthcare	Oncologists at Memorial Sloan-Kettering Cancer Centre in New York are using IBM's Watson supercomputer to provide chronic care and cancer treatment diagnostics by accessing knowledge from 600,000 medical evidence reports, two million pages of text from 42 medical journals, and 1.5 million patient records and clinical trials in the field of oncology.

How It Will Transform Companies and Society

Cognitive computing may have important effects in many sectors or business functions, such as call centre sales, administrative support, customer service, education and healthcare **[3]**. It is possible that by 2025, productivity gains of 40 to 50% could be achieved for the 125 million knowledge workers in categories that involve answering questions or carrying out tasks for other workers or customers, which would lead to economic impact of €1.7 trillion to €2.2 trillion per year **[3, 7]**. In the education sector, cognitive computing could also have important effects by augmenting teacher abilities and enhancing or replacing lectures with "adaptive" learning programs **[3, 7]**. In sectors related to technical professionals, by 2025, there is a potential economic impact of €1.0 trillion to €1.2 trillion per year **[3]**. In management, by 2025, it is possible that cognitive computing will lead to economic impact of €0.8 trillion to €1.1 trillion per year **[3]**. In professional services, it is possible that by 2025, productivity gains will lead to an economic impact of €0.6 trillion to €0.8 trillion per year **[3]**.

Technologies such as knowledge work automation tools move companies further to a future of leaner, more productive operations, but also far more technologically advanced operations **[4, 16]**. Companies will need to find ways to get the workforce they need, by engaging with policy makers and their communities to shape secondary and tertiary education and by investing in talent development and training. Many companies will need support in change management, technical installation, process redesign, and employee training as they upgrade their technology platforms. Technology providers, IT consultants, and systems integrators are likely to find new opportunities to help businesses make these transitions successfully, perhaps using knowledge work automation technology themselves to better manage projects and conduct advanced analyses.

There are also impacts for society as automation of knowledge work may bring, for example, improved quality of healthcare, faster drug and new medicines discoveries **[80]**.

Technology and Market Maturity

In terms of the technology development stage, cognitive computing is facing rapid advances in the last years, due to the evolution of other disruptive technologies such as mobile Internet, cloud computing and Internet of Things **[4]**. These rapid advances are reducing costs and boosting performance, making knowledge automation more attractive, as computing power continues to grow exponentially, although new jobs will appear, as it is being analyzed later **[16]**. Due to its potential to replace cognitive human tasks, it is not surprising if one states that there is a promising market for this technology. Artificial Intelligence-based systems have been increasingly developed, and as a result, the market for cognitive computing may dramatically boost in the near future.

Expected Impact on Economy and Jobs

Cognitive computing tools and systems could have as much as €5.2 trillion to €6.7 trillion in economic impact annually, by 2025, due to greater output per knowledge worker **[3]**. Of this total, the lion's share (€4.3 trillion to €5.6 trillion) could be generated in advanced economies where wage rates are higher.

Regarding the expected impact on jobs and employment, it is possible that automation of knowledge work could create disproportionate opportunities for some highly skilled workers and owners of capital, while replacing the labour of some less skilled workers with machines, which again stresses the importance of further developing education in digital skills. On the other hand, automation of knowledge work could also directly address serious gaps in the supply of workers who have the needed skills **[4, 16]** for the economy. It is expected that some categories of knowledge jobs could become partially obsolete **[81]**. Many knowledge worker jobs could be redefined, and if so, workers will need retraining, both to work with new technologies and to learn new tasks and skills as their jobs evolve. This may spark complex societal challenges, particularly in the education and retraining of workers. Although many less skilled jobs will be lost, automation of knowledge work could drive the creation of many new types of jobs if businesses and governments can innovate effectively and adjust education and training to focus on new skills.

Legislation and Regulation Issues

In addition to dealing with the employment and macroeconomic effects of these technologies, policy makers and business leaders will be confronted with legal and ethical considerations **[6, 11]**. Regulators and courts will need to learn how to decide upon accountability and liability; if harmful decisions are made by computers, for example, who will be responsible if a computer gives an inappropriate medical treatment advice? Organisations may require human involvement to always make or approve final decisions, but it is likely that decisions and analysis become so complex they exceed most people's ability to fully understand or audit them. This will imply the design of solutions that consider a comprehensive approach to the liability of decision-making, adopting a more holistic perspective of integrating human, technology and corporate responsibilities **[11]**.

Enablers and Hindrances

Realizing the full potential impact of knowledge work automation will involve overcoming some technological, regulatory, and organizational hurdles **[4]**. Artificial intelligence will still have to develop significantly before the envisaged benefits can be realized. Cultural and organizational hurdles will also exist. For example, risk-averse firms may delay adoption until the benefits of these technologies have been clearly proven, or business leaders might have concerns about legal liability regarding situations in which these technologies can make mistakes (e.g. with a patient diagnosis).

How Cognitive Computing is transforming highly skilled jobs

Disruption by IBM's Watson

IBM Watson is a technology platform that uses natural language processing and machine learning to reveal insights from large amounts of unstructured data **[9]**. Through cognitive computing, IBM Watson can answer questions posed by the most pressing customers; quickly extract key information from all documents; and reveal insights, patterns and relationships across data. Watson analyses unstructured data, with 80% of all data today being unstructured. This includes news articles, research reports, social media posts and enterprise system data. IBM Watson first learns a new subject with all related materials being loaded into Watson, such as Word

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documents, PDFs and web pages. Questions and answers pairs are added to train Watson on the subject. Watson is automatically updated as new information is published. Then Watson answers a question by searching millions of documents to find thousands of possible answers, collects evidence and uses a scoring algorithm to rate the quality of this evidence, ranking all possible answers based on the score of its supporting evidence.

Oncologists at Memorial Sloan-Kettering Cancer Centre are, for example, using IBM's Watson computer to provide chronic care and cancer treatment diagnostics **[9]**. Knowledge from 600,000 medical evidence reports, 1.5 million patient records and clinical trials, and two million pages of text from medical journals, are used for benchmarking and pattern recognition purposes. This allows the computer to compare each patient's individual symptoms, genetics, family and medication history, etc., to diagnose and develop a treatment plan with the highest probability of success.
Another example of IBM's Watson usage is the ROSS Intelligence **[12]**, a digital legal expert that helps power through legal research. The process is to ask questions in plain English, as would to a human lawyer or legal expert, and ROSS then reads through the entire body of law and returns a cited answer and topical readings from legislation, case law and secondary sources to get answers up-to-speed quickly. In addition, ROSS monitors the law around the clock to notify of new court decisions that can affect the case.

Changing Human-Computer interface with Siri
Apple's Siri is another example of cognitive computing, though in a less sophisticated approach. Siri enables people to talk to Apple's iPhone as one would to a friend and it can make things done – like sending messages, placing calls, and making dinner reservations **[13]**. Siri works hands-free, so it can be asked to show the best route home while a person is driving. It works with HomeKit to let voice be the remote control for Apple-connected products at home. And it works with Wikipedia, Yelp, Rotten Tomatoes, Shazam, and other online services to get answers to broader knowledge areas.

2.1.4 Internet of Things (IoT)

Features

Internet of Things can be defined as the use of sensors, actuators, and data communications technology built into physical objects – from roadways to pacemakers – that enable those objects to be tracked, coordinated or controlled across a data network, or the Internet **[10]**. Its grand vision is a world of networked intelligent objects.

One of the key features of the Internet of Things systems is that they are built on direct communication between different devices and objects, typically in near-real-time, that enable them to monitor their environment, report their status, receive instructions, and even take action based on the information they receive.
Following, **Table 4** shows some examples of application for the Internet of Things.

Table 4 Examples of application of Internet of Things [7]

EXAMPLE OF APPLICATION	DESCRIPTION
Public security	To use sensor data to improve policing.
Energy	To use sensor to monitor and control power grids and water systems; To map unexplored fossil fuel fields to pinpoint deposit locations.
Public infrastructures	To use sensor data to gather information and manage urban infrastructure, systems, and services, including traffic, garbage and water systems, and public safety.
Healthcare	To use sensor data to monitor people with chronic diseases; or to alert a doctor when the heart rate of a patient with a remote monitor spikes.
Industry	Companies are using sophisticated Internet of Things technologies to manage the performance of individual machines and systems – an assembly line full of robots and other machines.

How It Will Transform Companies and Society

The Internet of Things also has the potential to disrupt the companies' realities and lead to significant operational improvements, delivering new kinds of customer service and higher-quality products. However, multiple technological and organizational challenges may also arise **[3]**. It will be of critical importance to understand and design how to use the Internet of Things in production, logistics, customer service or sales.

Internet of Things technology is also expected to have an impact on human lives and well being and healthcare **[3, 4, 7]**. For example, in healthcare, doctors now perform "capsule endoscopy" using a pill-shaped micro-camera with wireless data communication capabilities that travels through a patient's digestive system and transmits images to a computer **[3]**. Also, the use of IoT-based wearable devices such as Apple Watch or Fitbit, which continuously measure some basic but relevant indicators on people's health like the heartbeat, when combined with Big Data algorithms, can provide significant advances to public healthcare or precision healthcare **[80]**.

Technology and Market Maturity

Regarding the technology development stage, the Internet of Things is still in its early stages of adoption, but it already has a wide variety of uses, and the portfolio of applications is expanding daily. However, the evolution of the technology is happening very fast and its adoption rate has significantly increased in the last 2 years, becoming quite popular in consumer products, along with a slower but increasing adoption rate in the manufacturing environment.

Expected Impact on Economy and Jobs

The economic impact of the Internet of Things technology is estimated to be around €2.7 trillion to €6.2 trillion annually, by 2025 **[3].** Significant impacts will be achieved in economic sectors such as manufacturing, healthcare, transportation, security and utilities **[2, 3, 5]**. The largest impacts among these applications would be in healthcare and manufacturing. Across the health-care applications, Internet of Things technology could have an economic impact of €1.1 trillion to €2.5 trillion per year, by 2025 **[3]**. In manufacturing, the estimated economic impact is of €900 billion to €2.3 trillion per year, by 2025. Adding sensors to automobiles to prevent crashes could also create economic value of as much as €50 billion per year, by 2025 **[3]**.

Legislation and Regulation Issues

Due to the distinctive characteristics of this technology, businesses will be challenged to make the most effective use of this technology, given the level of innovation and technical expertise that will be required and the level of security that may be needed. Policy makers will likely have a long list of issues to resolve to allow the benefits of Internet of Things applications while protecting the rights and privacy of citizens **[6, 11]**. For example, in terms of public policy, government leaders will need to establish clear understandings of the privacy risks that accompany the Internet of Things. The ability to put sensors virtually anywhere – to observe the traffic on a residential street or to monitor a home's electricity use – will undoubtedly raise serious concerns about how all that information will be used **[7]**. Another important concern is that computer systems and networks could be the targets of criminals, terrorists, or even just hackers trying to prove a point **[6, 11]**. Since sensors and networks are now controlling critical systems such as the electric grid, consequences of attacks on these systems could be devastating. There are no obvious security solutions and, once again, public policy makers and regulators will need to work together to increase security and find a balance between enabling innovative IoT solutions and reducing its risks. Hence, there are still many technical, financial, and regulatory issues to be resolved. For example, early adopters may be required to prove that sensor-driven business models create superior value in the face of the emerging security and privacy risks.

Enablers and Hindrances

On the technology side, the cost of sensors and actuators must fall to levels that will spark widespread use **[4, 5]**. Also, technology providers need to agree on standards that will enable interoperability between sensors, computers and actuators, and investing in Internet of Things applications will require extra effort to build and maintain integrated systems **[10]**. Progress is also needed to create software that can aggregate and analyze data and convey complex findings in ways that make them useful for human decision makers or for use by automated systems, while taking into account the balance between the drive for economic and social development and the rights of users to privacy and security **[11]**.

Sensors Everywhere

The term 2Internet of Things2 (IoT) was coined by British entrepreneur Kevin Ashton in 1999, while working in Auto-ID Labs at MIT, referring to a global network of Radio-frequency identification (RFID) connected objects. But the technology has existed for a long time. In Portugal, Via Verde technology pioneered the massive use of IoT in cars in the early 1990s, but in the late 1990s services like the GPS tracking of lorries by the company INOSAT became widely available.

Perhaps the most recent famous application of the Internet of Things are smart thermostats. Regular old thermostat can be hooked up to the Internet and communicate with people. These smart thermostats are able to be adjusted from outside the house with the simple touch of an application. They are pre-programmable and have learning abilities for private preferences. The most famous of these thermostats is Nest thermostats, a company that was bought by Google, in 2013, by a staggering amount of €3.2 billion.

In healthcare, IoT can be used for medication control by connecting a pill box with the Internet. The pill box then can tell the last time was the pill bottle was opened and signal the need to take the next pill. Originally conceived to help the elderly, this application can be used by anybody who needs to keep track of their medications dosage. This is a basic use of an IoT application, but it is of life importance. Line Health is a promising Portuguese startup looking to penetrate the market.

Smart watches, like Apple Watch, Withings Activité or Samsung Gear, are the new hype of IoT. Instead of regular watches that just show the time, smart watches are connected to the Internet and to your phone. They help gather all kinds of additional data, for example, when exercising, they can track the person’s heartbeat.

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Yet, many believe that the major promise will come from putting sensors in industrial machines and equipment, in the manufacturing environment, often referred to as Industry 4.0 **[2]**. An example is General Electric (GE)'s Durathon battery plants, where over 10,000+ sensors measure temperature, humidity, air pressure and machine operating data in real time. This not only gives the opportunity to monitor production and adjust processes in real time, but also to trace battery performance back to specific batches of powder and at every step along the process.

2.1.5 Big Data

Features

Big Data is about large volumes of data, structured and unstructured, that uses specific technology for collecting, storing and analyzing datasets that cannot be acquired, managed, and processed by traditional IT tools within a tolerable time **[3, 7, 56]**. Big Data is often characterized by volume (petabytes-size of the various types of data generated from different sources); variety, referring to use various types of structured, semi-structured, and unstructured data; and velocity, referring to the rate at which data is generated and the speed at which it should be analysed and acted upon **[56]**.

Big Data is often associated with technology for predictive analytics grounded on large volume of data, from multiple sources and formats and that is processed and analyzed at a very fast speed. Sources for Big Data can be very disparate, from social networks to mobile computing, GPS location, sensors in vehicles, houses, etc.

How It Will Transform Companies and Society

Big Data is mainly about predictions, applying sophisticated algorithms to huge quantities of data in order to infer probabilities of occurrences of a certain phenomenon. Big Data derives its ability to predict behaviour from the large quantities of data from the complex mathematical models and algorithms that are applied, obtaining correlations and inferences with high accuracy **[4, 56]**. Big Data technology is able to automatically lead organizations to uncover patterns, correlations and insights, and thus develop new knowledge and capabilities. This can have a tremendous impact on all functions of organizations. Big Data is currently being used by corporations to predict customers' behavior, suppliers' performance, equipment failures and planning preventive maintenance, as well as to increase fraud detection **[58]**. Big data is also expected to have a significant impact on healthcare and disrupt the way society will deal with healthcare issues **[80]**. There is a myriad of different ways new service and product providers are taking advantage from Big Data, from pharmaceutical companies for better understanding the effectiveness of their products, to medical doctors and caretakers that may have access to patients' real time data and be able to monitor and proactively control patients conditions. Big data can also be used for predicting outbreaks of infectious diseases like malaria or dengue, or for study how climate, location and other variables may impact health issues like respiratory conditions, asthma, flu or bronchitis **[80]**.

Technology and Market Maturity

Big Data is a technology that has progressed considerably in the last 3 years and it is becoming an established technology in many of mainstream companies. Big Data has two main components: the data analysis and prediction algorithms and models – that are reasonable matured – and the sourcing and storing of data sets – still in a very embryonic and volatile configuration **[7]**. Moreover, Big Data is quite interwoven with other technologies like Cloud Computing, Internet of Things, Mobile Computing, that can be potential sources of data sets, and thus its evolution is very much dependent on how they will be used in the future **[58]**.

The Big Data market is becoming already a reality in many corporations **[56]**. In the banking sector, for example, Big Data is used to understand customers and boost their satisfaction, but also to minimize risk and fraud while maintaining regulatory compliance **[69]**; in the retail sector, where customer relationship building is critical, many companies use Big Data to analyse customers consuming patterns and their characteristics as individuals or families, offering promotions and targeted marketing, accordingly **[58]**. Although Big Data technologies are rapidly being deployed in many companies, they need to be accompanied by similarly dramatic shifts in how data supports decisions and product/service innovation of companies, and many managers are still lacking the capability to take advantage of existing analytic tools.

Expected Impact on Economy and Jobs

Big Data is expected to have an important economical impact, particularly when connected with other technologies like Internet of Things, Cloud Computing or Cognitive Computing. It can generate value up to 1.1 trillion euros **[57]**, by decreasing maintenance downtime, thus less expenditure, and increased asset utilization; increasing revenue through faster and innovative products and services derived from data analytics with higher levels of customer satisfaction; better monitoring and control of production lines and logistics routing optimization; and improving buildings energy efficiency through more intelligent and dynamic energy optimization. Also there is tremendous scope to deploy Big Data analytics in governmental functions, from procurement to tax collection, and the administration of public benefits **[4, 7, 57]**. Big Data can improve public-sector productivity and make government more transparent, responsive, and cost-effective. Policy makers can also harness Big Data technologies to compute outcome monitoring and control.

Hence, it is expected an upsurge of value and demand for data scientists or analytics, especially for those that combine data analytics knowledge with domain expertise, for example, in the fields of healthcare, finance, energy efficiency, equipment maintenance, etc. With the potential automate predictions, Big Data can have a strong impact on many professions that require analytic skills, and these jobs are likely to need to evolve and adapt to the existing requirements of using these tools **[81]**. Hence, medical doctors, auditors, operations and logistics managers, or plant and equipment planers will have to learn on how to use Big Data tools to enhance their decision making capabilities or may face the risk of being displaced.

Legislation and Regulation Issues

Like with Internet of Things or Cognitive Computing, policy makers will likely face some challenges related to protecting the rights and privacy of citizens **[6, 11]**. Collecting and analyzing non-anonymous data about people's behaviour and organizations' performance will undoubtedly raise serious concerns about how all that information will be used. An important concern is that data may be targeted by criminals, terrorists, or just hackers trying to obtain a benefit or prove a point. Public policy makers, regulators and private entities will need to cooperate and establish clear understandings of the privacy issues that accompany Big Data. They will need to work together in order to strike the right balance between enabling Big Data and reducing its risks.

Enablers and Hindrances

The cost of software solutions that can collect, store, aggregate, analyze data and convey complex findings, in ways that make them useful for human decision makers or for use by automated systems, has been decreasing considerably, and it is possible today to use Big Data tools supported by Cloud Computing infrastructure **[57, 69]**. In addition, over the last few years, some startups have emerged, providing outsourcing services on data analysis over the cloud, where companies only need to upload data sets, results of analysis and suggestions for decision-making. As a downside, the combination of tools like Big Data, Internet of Things and Cognitive Computing may also pose rising risks of malfunction with negative consequences **[11]**. The lack of understanding of Big Data possible risks and limitations may, in turn, pose even greater risks if people subvert the outcomes and power brought by these tools. The danger of misusing technology, whether intentionally or unintentionally, may hinder or inhibit a wider deployment of Big Data applications.

How Waze disrupted mobile GPS products with Big Data

The Israeli startup WAZE created a disruptive system for the mobile-based automotive GPS solutions that were emerging through the deployment of NOKIA, IPhone or Android-based mobile phones **[58]**. Waze founders understood that a major improvement to existing automotive GPS solutions, at the time, was to introduce actual traffic data on the calculation of the optimal trip. Their genius solution was to crowdsource real-time road and traffic information through the users' feedback on the location and the speed of cars and use that information into the calculations of the path. This disruptive approach was a tremendous success, particularly with the competing Navteq-based solution grounded on physical sensors in major world cities. Recognizing the power of having a Big Data based solution for automotive transport, Google bought Waze in 2013 for a staggering amount of 1,1 billion dollars – an incredible figure for a company with less than 100 employees and no physical assets.

The power of Big Data in Agriculture

Climate Corp. was founded in 2006 aimed at capitalizing on the increasingly unpredictable climate conditions. The company started by offering insurance against weather-related incidents such as a rainout for major tournaments or concert cancelations. The company evolved to new markets, settling on a business model that revolved around providing a new type of insurance to farmers, covering the profit, and it did so in a very innovative way, by turning the USA into a grid, and use weather data to measure temperature, rainfall and other factors **[59]**. Farmers buying coverage for drought that didn't receive the specified amount of rain covered by the policy were paid automatically by Climate Corp., based on the measurement, with no need to file claims. The company had developed the agriculture industry's most advanced technology platform, combining local precise weather monitoring, agronomic data modeling, and high-resolution weather simulations to deliver a complete suite of full-season monitoring, analytics and risk management products **[59]**. In 2013, Monsanto acquired the Climate Corp. for 930 million euros.

How Big Data can change Public Health

Traditionally, national population health surveys have been based upon acute health conditions but, in recent decades, the focus has moved to chronic conditions as well, requiring smaller measures over longer time periods. Mobile health monitors, where mobile computing technologies eliminate manual administration, will provide richer data sets for health measurement **[80]**. Older technologies of telephone interviews will be replaced by newer technologies of smartphone sensors (ou smartwatchs)

▶

to provide deeper individual measures, at more frequent timings, across larger-sized populations. Such continuous data can provide personal health records, supporting treatment guidelines specialized for population cohorts. Evidence-based medicine will become feasible by leveraging hundreds of millions of persons carrying mobile devices interacting with Internet-scale services for Big Data analytics **[58, 80]**. After Apple launch its Apple Watch, its Health Kit was presented as a way for developers create mobile applications for healthcare. More recently, Apple has started collecting some of the research data that users submit through apps using the company's ResearchKit platform. For certain ResearchKit studies, Apple will be a researcher, receiving data from participants who consent to share their data, exploring how the technology can improve the way people manage their health. The first two apps Apple is collecting data from include the Mole Mapper Melanoma Study app and the Parkinson mPower study app. Apple has also unveiled the CareKit as an open-source framework that provides another element to its work, with HealthKit and ResearchKit, by offering a platform for patient-facing data that can be shared with physicians and family.

2.1.6 Additive Manufacturing / 3D Printing

Features

3D Printing refers to additive manufacturing techniques that create objects by printing layers of material based on digital models **[2, 3, 8]**. As opposed to traditional injection molding, casting, or other "subtractive" manufacturing processes, additive manufacturing takes a digital file and creates three-dimensional objects by printing successive layers or materials that are then modified slightly to create the desired end product **[2]**. 3D Printing takes advantage of the way computer printers work: they deposit a very thin layer of material (ink, traditionally) on a base (paper) in a pattern determined by the computer **[4]**.

Current limitations of 3D Printing, which vary by printing technique, include relatively slow build speed, limited object size, limited object detail or resolution, high materials cost and, in some cases, limited object strength **[3, 4]**. However, in recent years rapid progress has been made in reducing these limitations.

Following, **Table 5** shows some examples of application of 3D Printing **[2, 3, 4]**.

Table 5 **Examples of application of Additive Manufacturing / 3D Printing [2, 4, 5, 7]**

EXAMPLE OF APPLICATION	DESCRIPTION
NASA	3D is being used for final parts, ranging from plastic vents and housings on NASA's next-generation Moon rover, to a metal prosthetic jawbone for an eighty-three-year-old man; NASA is exploring the use of 3D printers in the production of parts for rocket engines that will power human space travel.
Automotive	In the near future, 3D Printing might be used to print out replacement parts for faulty engines on the stop instead of maintaining stockpiles of them in inventory.
Construction	Demonstration projects have even shown that the technique could be used to build concrete houses.
Aeronautic/ Aerospace	Boeing currently prints 200 different parts for ten aircraft platforms. In healthcare, manufacturers have been offering printed custom hearing aid earpieces.
Healthcare	The dental appliance maker Invisalign produces 50,000 to 60,000 appliances per day, using stereo-lithography printers.
Biomedical	Scientists are exploring, for example, how to use 3D Printing to produce micro-robots that deliver medicine inside the human body, or how to create a skin-like material.

How It Will Transform Companies and Society

3D Printing addresses concerns about the waste and environmental impact of traditional manufacturing processes. Direct product manufacturing, using 3D Printing, can reduce the number of steps required for parts production, transportation, assembly and distribution. It can also reduce the amount of material wasted, in comparison with subtractive methods **[2, 3]**. Many predict that this technology will eventually displace a myriad of traditional manufacturing processes. The approach of ubiquitous 3D Printing, coupled with the on-going development of the technology itself, will force many companies to rethink their businesses and business models **[7]**. Mould makers, for example, could see their model disrupted, or perhaps strengthened, by one of the many evolving sub-niches of 3D Printing, namely printers capable of making very large moulds from layers of paper laminated together **[2, 3]**. Companies will also have to rethink the individual capabilities necessary for success, as product development strategies, organisation structures, legal capabilities, logistics, and outsourcing strategies might all need to be adjusted.

For the society, in the longer term, perhaps beyond 2025, bioprinting of living organs has long-term potential to save or extend many human lives **[4, 14]**. Societies can benefit from products that are made with less waste that do not require transport over great distances and, therefore, have less impact on the environment.

Technology and Market Maturity

Although the technology is already well developed, 3D printing continues to mature and grow **[2]**. The performance of additive manufacturing machinery is improving, the range of materials is expanding, and as a result prices (for both printers and materials) are declining rapidly **[57]**.

In terms of the market development stage, 3D printing is likely to become widespread over the coming decade. Industry analysts agree that 3D printing is a fast-growing, multibillion-dollar market, but the projections for market growth across industries vary widely, with estimates ranging from €9 billion to €21 billion by 2020 **[2]**. Sales of personal 3D printers grew 200 to 400% every year between 2007 and 2011, and 3D printers are already commonplace for designers, engineers, and architects, who use them to create product designs and prototypes **[3, 7]**. 3D printing is also gaining traction for direct production of tools, molds, and even final products.

Expected Impact on Economy and Jobs

The potential economic impact of 3D Printing is estimated to be of €230 billion to €550 billion per year **[3]**. The largest source of potential impact would come from consumer uses, followed by direct manufacturing (i.e., using 3D Printing to produce finished goods) and using 3D Printing to make moulds.

Although the access to 3D Printing could actually make some manufacturing sectors more competitive, this may not create many manufacturing jobs, as the 3D Printing process is highly automated **[8]**. Additive Manufacturing enables manufacturers to create complex parts in one step, eliminating the need for assembly and inventories of individual parts. New jobs in 3D computer-aided design and 3D modeling are being created in R&D and engineering, while jobs are being lost in parts assembly.

Legislation and Regulation Issues

As for the previous technologies, legislation and public bodies must be configured to deal with the technology. Policy makers should consider supporting the development of 3D Printing, in particular by funding research in 3D Printing technologies. The challenges for policy makers include addressing regulatory issues – such as approving new materials for use – ensuring appropriate intellectual property protections, and assigning legal liability for problems and accidents caused by 3D-printed products **[3, 7]**.

Enablers and Hindrances

Despite improvements in 3D Printing technology, remaining limitations, particularly material costs and build speeds, could constrain wide-scale adoption **[2]**. For example, in the healthcare sector, 3D Printing faces some fundamental barriers, such as the lack of knowledge regarding the impact of materials on the human tissue, the high costs, quality concerns, and the acceptance by healthcare providers, payers, and patients **[14]**. The success of 3D Printing also depends on improvements in products such as design software, 3D scanners, and supporting software applications and tools **[3]**.

3D Printing for the human body

Oxford Performance Materials (OPM) is an original equipment manufacturer (OEM) of medical devices that utilize the company's OsteoFab® process, which combines laser sintering additive manufacturing technology and OPM's proprietary material formulation to 3D print orthopedic and neurological implants **[14]**. The adoption of OsteoFab® implants over metallic and other polymeric options appears to be driven by a combination of 3D Printing technology attributes: desirable economics, biocompatibility, radiolucency, and bone-like mechanics and behavior. The company has obtained clearance from the Food and Drug Administration (FDA) to its SpineFab VBR Implant system. According to the company's press release, OPM's SpineFab system is the first and only FDA cleared 3D printed load-bearing polymer device for long-term implantation. The company obtained also FDA clearance for its 3D printed patient-specific device for facial reconstruction. The OsteoFab® Patient Specific Facial Device (OPSFD) is individually designed for each patient for enhancement, to correct trauma, and/or to correct defects in facial bone. The OPSFD is constructed with the use of the patient's CT imaging data and computer aided design to determine the dimensions of each implant; the device is then manufactured via the OsteoFab® 3D printing laser sintering process **[14]**.

The industry of orthotics has also seen a renaissance of sorts ever since 3D Printing technology was introduced to the human foot. Companies such as SOLS and Wiivv Wearables have commandeered the consumer orthotic market by offering insoles that are not just 3D printed, but are also custom designed to fit the user's foot. Wiivv Wearables, in particular, is attempting to provide an insole that is both supportive and stylish, and have been slowing building hype during their early stages of development. Recently, venture capital firms, including Eclipse VC, Real Ventures, Asimov Ventures, and others, came together to invest €3.5 million in Wiivv Wearables during their seed round funding. Wiivv will use the funds to help manufacture and distribute their BASE custom-made 3D printed insoles, which are specially designed to each foot in order to optimally prevent foot pain and provide comfort and support to the wearer. The Wiivv team has also developed a new concept called the Adaptive Manufacturing System that works by digitally capturing the human body and manufacturing the wearable on the spot.

2.2 ROBOTICS

2.2.1 Autonomous Vehicles

Features

An Autonomous Vehicle (AV) is one that can manoeuver with reduced or no human intervention **[3, 4]**. Machine vision is a key enabling technology for autonomous vehicles. The use of cameras and other sensors, acquiring an image and then extracting relevant information (such as stop signs or objects in its path) on which to base actions **[4]**, enabled by the connection to a computer that constantly monitors the road and the surrounding environments.

How It Will Transform Companies and Society

At the economic sector level, autonomous vehicles have significant potential to transform ground transportation, creating many opportunities for businesses and addressing many societal needs **[7]**. They also have the potential to affect everyone who uses a car, all industries related to cars and trucks, and intermodal logistics systems. The success of autonomous cars and trucks could change the auto insurance industry **[4]**. A significant reduction in traffic accidents and insurance claims could lead to a corresponding reduction in premiums **[7]**. Eventually, this could even drive a shift from traditional personal auto insurance to product liability insurance.

At the society level, the potential benefits of autonomous cars and trucks include increased safety (reducing deaths from motor vehicle crashes), reduced CO_2 emissions, and more leisure or work time for motorists. 30,000 to 150,000 lives could be saved per year, by 2025, if self-driving technology is adopted, and CO_2 emissions could be reduced by as much as 300 million tons per year **[3]**. The widespread adoption of AVs could also recover up to 80 billion hours lost to commuting and congestion **[2]**. This can be an extremely important lever for the sustainability of large and mega cities around the world. Moreover, AVs may also contribute to increased mobility of disabled people, allowing people hampered from traditional driving to become more autonomous on their mobility.

Technology and Market Maturity

Regarding the technology development stage, by 2015, some enterprises are still testing their autonomous vehicles as disruptors in the auto industry (e.g. Google and Apple, though often spoken about, but yet not confirmed). Even though the regulatory framework for autonomous vehicles is not yet in place (California and Nevada are permitting testing on public roads), major automakers are moving ahead with development. Companies like General Motors, Toyota, Mercedes-Benz, Audi, BMW, and Volvo are all testing their own autonomous systems. As the technology is still being tested, the market is yet at a very early stage.

Regarding the expected impact on jobs and employment, self-driving vehicles could have very disruptive effects on the trucking industry. For example, in the United States, there are around 3.5 million truck drivers, and demand for long-haul truck drivers would decline significantly, relegating truck driving to final-mile transportation and delivery **[3]**. The job of truck driver may come to involve more customer service, for example. Other driving jobs, such as taxi drivers and bus drivers, could also be at risk in the long term.

Expected Impact on Economy and Jobs

Estimations forecast that, if regulators approve autonomous driving and the public accepts the concept, the benefits provided by improved safety, time savings, productivity increases, and lower fuel consumption and emissions could have a total economic impact of €200 billion to €1.9 trillion per year, by 2025 **[3, 7]**. Self-driven trucking could have a potential economic impact of €100 billion to €500 billion per year, in 2025 **[3]**. However, while the economic impact driven by this technology could be quite large, it may take many years to fully materialize.

Legislation and Regulation Issues

In order to realize benefits such as reduced congestion, infrastructure investments would be needed to create special lanes and install sensors to control traffic flow on major arteries. There will be also legal and ethical questions to address, such as who bears responsibility when an autonomous vehicle causes an accident and how to program a computer to make life-and-death decisions **[11].** These issues are already under technical discussion in some states in US, where pilot AV are deployed in real world context. Policy makers will need to devise thoughtful supporting regulations for autonomous vehicles.

Autonomous vehicles will also present legitimate security concerns. Like any computer system, a car's autonomous guidance system could be hacked, with potentially disastrous results. Robust cyber security systems will need to be in place before this technology hits the road **[6]**.

Enablers and Hindrances

There are enablers and hindrances to the evolution of the technology. For example, government efforts to encourage the development and ultimate adoption of autonomous cars and trucks could greatly speed their impact by helping to overcome concerns about technology, safety, liability, and legal responsibilities **[4]**. Laws regarding autonomous driving will be a critical enabler, and if governments establish regulations early, on letting autonomous vehicles travel on public roads, it will provide a foundation on which to build new approaches to ground transportation. However, if regulations forbid drivers to take their hands off the wheel under any circumstances, the savings from autonomous driving time will not materialize **[3]**. Also, despite the technological progress that is now being seen in experimental vehicles, these systems still require a great deal of improvement of vision, pattern recognition, and artificial intelligence technologies to account for unexpected issues in infrastructure **[4]**.

Self-Driving car by Google

Google has been at the forefront of developing a prototype vehicle that is designed to take people where they want to go at the push of a button – no driving required **[15]**. Google car is able to navigate city streets through teaching cars to navigate through many complicated scenarios on city streets. Cars use their sensors and software to sense objects like pedestrians, cyclists, vehicles and more, and are designed to safely drive around them **[15]**. The car processes both map and sensor information to determine where it is in the world. The car knows what street is on and which lane is in. Sensors help detect objects all around. The software classifies objects based on their size, shape and movement pattern. It detects and distinguishes a cyclist from a pedestrian. The software predicts what all the objects around might do next. It predicts that the cyclist will ride by and the pedestrian will cross the street. The software then chooses a safe speed and trajectory for the car. The car nudges away from the cyclist, or slows down to yield to the pedestrian. Since 2009, Google cars self-driven over 1.6 million kilometers and are currently out on the streets of Mountain View, California and Austin, Texas **[15]**. The testing fleet includes both modified Lexus SUVs and new prototype vehicles that are designed from the ground up to be fully self-driving. There are safety drivers aboard all vehicles for now.

Other main car manufactures are also in full throttle, testing the self-driving technology in real world environments. One of those brands is Audi, and in January 2015, an Audi A7 drove 885km from Silicon Valley to Las Vegas with company officials and journalists on board, with the car driving itself at speeds of up to 110 km/h. In April, an Audi Q5 modified by Delphi, drove from San Francisco to New York over nine days in autonomous mode 99% of the time. When the new A8 goes on sale, its Piloted Driving tech will be capable of fully automatic parking and on-road driving at speeds up to 60km/h. (Intended for traffic jams on throughways without traffic signals – the highway – the system will brake, steer and accelerate, all on its own, in dense traffic).

2.2.2. Advanced Robots

Features

Advanced Robots can be referred to as those with enhanced senses, dexterity, and intelligence used to automate tasks or augment humans **[16]**. One of the key characteristics of this new generation of robots is the ability to substitute machines for human labour and learn from and interact with humans **[3, 15]**. To make these tasks possible, they have high-definition machine vision and advanced image recognition software that allows them to position objects precisely for delicate operations and to discern a part in a pile **[4]**.

Following, **Table 6** shows some examples of application of Advanced Robots **[2, 3, 7]**.

Table 6 **Examples of application of Advanced Robots [2, 4, 7, 16]**

EXAMPLE OF APPLICATION	DESCRIPTION
Production line	By 2025, advanced robots could be capable of producing goods with higher quality and reliability, by catching and correcting their own mistakes and those of other robots or humans.
Search and rescue operations	Gathered in teams, these robots could eventually be used for dangerous tasks such as search and rescue operations.
Healthcare	Ultraprecise surgical robots are making new forms of minimally invasive surgery possible, that can reduce postsurgical complications, enable faster recovery, and possibly reduce surgical death rates.
Automotive assembly-line	A robotic device could be used to relieve a line worker from physically demanding tasks, as well as to improve ergonomics.
Construction	Advanced robots can be used as co-workers in construction tasks such as painting and material transportation.

How It Will Transform Companies and Society

For hospitals and healthcare providers, advanced robotics could ultimately offer substantial improvements in patient care and outcomes **[3]**. Manufacturing and service companies with large workforces could benefit from reduced costs, reduced injuries, and lower overhead, as well as reducing payrolls in human resources, labour relations, and factory supervisory roles **[2]**. Factories might no longer need to be located near sources of low-cost labour, allowing them to be located closer to final assembly and consumers, simplifying supply chains and reducing warehousing and transportation costs.

The companies will be affected, for example, by the reconfiguration of manufacturing processes, and service delivery channels **[2]**. Training employees to work effectively alongside robots is challenging. In order for businesses to take advantage of their potential and have a leading edge on the markets, they should continually experiment with advanced robotics and additional automation, identify promising technologies, rethink business processes, and develop in-house talent **[3]**. They should also consider how their supply chains could be redesigned to leverage automation, and how additional speed to market, flexibility, and quality could help differentiate their offerings from those of competitors **[2, 4]**. Companies will also need to rethink decision-making authority, for example as robots should be allowed to initiate emergency repairs on production machinery without human intervention, and thus shortening action **[2]**.

Technology and Market Maturity

In terms of the technology development stage, manufacturers in many industries have long used robots to tackle complex assignments, but robots are evolving for even greater utility **[2, 3]**. The main difference is that robots are becoming more autonomous, flexible, and cooperative. Robots are likely to interact with one another and work safely side by side with humans and learn from them. These robots will cost less and have a greater range of capabilities than those used in manufacturing today.

Regarding the market development stage, the technological advances, combined with declining costs, are making entirely new uses for robots possible **[2]**. The recent interest of the military in advanced robots which can be used to automate combat (similar to remotely piloted drone aircraft) and support human troops, could greatly speed further advancement **[2, 3]**.

Expected Impact on Economy and Jobs

By 2025, advanced robotics could have a worldwide economic impact of €1.7 trillion to €4.5 trillion annually **[3]**. Much of this impact – €800 billion to €2.6 trillion – could come from improving and extending people's lives. An additional €700 billion to €1.4 trillion could arise from automating manufacturing and commercial service tasks **[3]**. The use of advanced robots for industrial and service tasks could potentially have an annual economic impact of €600 billion to €1.2 trillion in developed countries, and €100 billion to €200 billion in developing economies **[3]**. Finally, €200 billion to €500 billion in impact could arise from the use of time-saving household service robots. In the healthcare sector, the potential economic impact of robotic surgery and robotic prosthetics could be as much as €800 billion to €2.6 trillion annually, by 2025, based on saving lives and improving quality of life **[3]**.

In developed countries, across occupations such as manufacturing, packing, construction, maintenance, and agriculture, the potential cost savings using the estimated annual cost of advanced robots, compared with the annual employment cost of an equivalent number of workers, yields a potential economic impact of €600 billion to €1.2 trillion per year, by 2025 **[3]**. In services, if 25 to 50% of people in the developed world were to adopt the use of advanced robots by 2025, €200 billion to €500 billion worth of time savings could be realized.

For societies and policy makers, the prospect of increasingly capable robots brings potential benefits: growing national productivity, higher-quality goods, safer surgeries, and better quality of life for the elderly and disabled. But it also poses new challenges in employment, education, and skill training. In some cases, access to advanced robotics could cause companies to repatriate manufacturing operations from low-wage offshore locations **[2]**. Widespread use of robots could create new high-skill employment opportunities, though the larger effect could be to redefine or eliminate jobs. By 2025, tens of millions of jobs, in both developing and advanced economies, could be affected **[2]**. For example, it is estimated that greater use of robotics and computerization will reduce the number of jobs in assembly and production by approximately 610,000, although this decline will be more than offset by the creation of approximately 960,000 new jobs, particularly in IT and data science **[2]**. The job gains will result from demand for an additional 210,000 highly skilled workers in IT, analytics, and R&D roles, as well as the creation of approximately 760,000 new jobs resulting from the types of revenue growth from opportunities cited above. Industrial data scientists will be the job function experiencing the highest growth, with approximately 70,000 new jobs **[2]**. The increased use of software and IT interfaces will also cause demand to surge for IT solution architects and user interface designers. Most of the job losses will result from the introduction of robotics on the shop floor and the computerization of routine jobs **[2, 7]**. Job losses will reach 120,000 (or 4%) in production, 20,000 (or 8%) in quality control, and up to 10,000 (or 7%) in maintenance **[2]**. Routine cognitive work will also be affected where it is expected that more than 20,000 jobs in production planning will be eliminated. At the industry level, the expanding market for intelligent machinery will allow manufacturers of this equipment to add 70,000 jobs to their workforce, representing a 6% increase **[2]**.

Legislation and Regulation Issues

Regarding the way legislation and public bodies is configured to deal with the technology, established manufacturers may need to accelerate automation and invest in innovative product development or superior service quality to meet the competition and better differentiate their offerings.

Enablers and Hindrances

There are also enablers and hindrances to the evolution of the technology. Adoption rates for advanced robots will be determined by many factors, including labour market conditions. For example, in China, where wages and living standards are rising, workers are pressing for better working conditions, including relief from long hours of precise piecework that can lead to repetitive stress injuries **[2, 16]**. There are several important barriers that could limit adoption of advanced robotics by 2025. For example, although costs are declining, most industrial and many commercial service robots remain expensive, costing tens or hundreds of thousands of dollars per robot. Also, once robots are purchased and installed, it can still take time to redesign processes and flows to fully take advantage of their capabilities. Policies discouraging adoption of advanced robots – for example, by protecting manual worker jobs or levying taxes on robots – could limit their potential economic impact. Policy makers will face difficult questions regarding legal liability, such as determining who is at fault when service or household robots contribute to accidents or injuries, as we have seen before in other sections.

Collaborative Robots

Collaborative robotics is pinned as the next big thing in robots. However, so far, these robots have been relatively small and were working in a small area. This means that they were limited in the number of applications they could be used for. But recently, a wider range of applications became possible with the increase of the payload and the reach of a collaborative robot. Green CR-35iA is the world's strongest collaborative robot, designed and developed by a Japanese company FANUC **[17]**. It can lift up to 35kg. This capability combined with reach and safety certification, enable a whole range of manual processes that humans have had to do alone. Collaborative robot CR-35iA can do the heavy lifting, leaving humans free to do the more skilled work. A major difference from traditional robots is that it has a built-in anti-trap protection and soft rubber skin that keeps people safe, enabling the possibility of working alongside people. Human operators can guide the robot, teach it or simply push it away, if they need some space. This type of robot is a good combination of the positive advantages of industrial robots, but with safety devices that allow for safe collaboration. This is what is shaping the robot market today, collaborative robots helping humans with various tasks, in either small or heavy applications.

The new robot revolution is being fuelled by China. An example is Shenzhen Everwin Precision Technology, as earlier 2015, the electronics components-manufacturer announced plans to build China's first fully-automated factory **[18]**. Some 1,000 industrial robots will replace humans on production lines as the company seeks to boost productivity and find a lasting solution to a shrinking labour pool and rising wages. In the Guangdong region, which is often called the "world's workshop", more and more factories in the region are looking at replacing human labour with automation to make their products cheaper and their supply chains more efficient. As Reuters reported, the capital of Guangdong, Guangzhou, aims to automate 80% of its manufacturing production by 2020.

2.3 GENOMICS

Features

Next-generation Genomics can be described as the combination of next-generation sequencing technologies, Big Data analytics, and technologies with the ability to modify organisms, which include both recombinant techniques and DNA synthesis (that is, synthetic biology) **[7]**.

Next-generation Genomics marries advances in the science of sequencing and modifying genetic material with the latest Big Data analytics capabilities **[3, 7]**. With rapid sequencing and advanced computing power, scientists can systematically test how genetic variations can bring about specific traits and diseases, rather than using trial and error.

The most promising area of application for Genomics is healthcare, through the combination of Big Data on genealogy, historical clinical studies, and other health-related, sociological, economical, behavioral information. This combination of information can then be linked to genotype (DNA), by making it possible to better identify and diagnose people at high risk for conditions such as heart disease or diabetes, allowing earlier and more effective intervention **[3, 7, 80]**. Other areas in which genetic sequencing holds promise include immunology and transplant medicine, central nervous system disorders, pediatric medicine, prenatal care, and infectious diseases **[3, 7]**.

How It Will Transform Companies and Society

Taking a look at the impact on companies, it is possible that genetic sequencing could create major opportunities for companies and startups to manufacture and sell gene-sequencing equipment along with the various supporting systems and tools that could be required **[3, 7]**. The early entrants into this market can have the opportunity to define major industry standards and norms, including sequencing approaches, data standards, and integration with electronic health records **[80]**. They will also need to address funding entities like insurance companies and governments, by clearly demonstrating cost-effective efficacy improvements **[3]**, mainly through outcome-based type of contracts **[80]**.

Genomics have the potential to create huge benefits for society through uncovering new ways to diagnose and treat cancer, diabetes and other diseases, but it also brings significant risks. Genetically modified organisms could interfere with natural ecosystems, causing potentially disastrous results, including loss of species and habitats **[7, 80]**. Genomic technology raises privacy and security concerns related to the potential theft or misuse of personal genetic information stored on computers **[6, 11]**.

Technology and Market Maturity

Over the coming decade, Genomics technology could power rapid acceleration in the field of biology and create disruptive healthcare models. Desktop machines are already enabling gene-sequencing as part of doctors' diagnostic routine **[7]**. Combined with gene-sequencing, and although in a very early stage of development, synthetic biology can also become an important source of growth. With further innovations due, modifying organisms can become a new way to address healthcare. And while the technology is still very recent, there is already evidence for applications in science and business.

In terms of the market development stage, the rate of improvement in gene-sequencing technology over the past decade has been astonishing. When the first human genome was sequenced in 2003, it cost nearly €3 billion and took 13 years of work by teams of scientists from all over the world, collaborating on the Human Genome Project **[80]**. Now, a €1,000 sequencing machine could soon be available to sequence a human genome in a few hours **[7]**.

Expected Impact on Economy and Jobs

The potential economic impact of gene-sequencing in healthcare, agriculture, and the production of substances such as biofuels could be €700 billion to €1.6 trillion a year, by 2025 **[3]**, though about 80% of this potential value would be realized through extending and enhancing lives through faster disease detection, more precise diagnoses, new drugs, and more tailored disease treatments. For example, the impact of disease prevention and treatment applications could be €500 billion to €1.2 trillion per year, in 2025 **[3]**. In agriculture, analysing plant genomes could lead to a potential economic impact of €100 billion to €200 billion per year, in 2025 **[3]**.

Legislation and Regulation Issues

Legislation and public bodies also play a significant role. Governments, for example, have yet to address major questions concerning who should own genetic information, what it can be used for, and who should have access to genomic capabilities **[7]**. Governments, besides guaranteeing clarity about ownership of DNA data and confidentiality, should also facilitate the accumulation of genetic information that should be used for improving public health **[80]**.

Enablers and Hindrances

One of the main hindrances to the evolution of the technology is that there is still much that scientists do not understand about genomics **[80]**. Obtaining interrelationships between genes, cellular mechanisms, organism traits, and environment is a complex undertaking that gene-sequencing can speed up **[3, 7]**. What is more likely to slow progress, however, are the many unresolved regulatory and ethical issues that this technology poses. One issue is the ownership of the data of sequenced genomes, which might not be available, if patients own the data regarding their own genomes and are not willing to share it **[3]**. Concerns regarding the confidentiality of patient DNA information will also pose issues with health insurers, as they could deny coverage or raise rates **[3]**. There are also concerns about whether or not patients should be given all the information about disease-linked mutations found in their genomes that might someday lead to illness **[80]**. Hence, moral and ethical questions can slow down progress and potentially encounter public resistance.

Genomics combined with cognitive computing

Pathway Genomics is a startup based in San Diego and the company's accredited clinical laboratory provides physicians and their patients in more than 40 different countries with actionable and accurate precision healthcare information to improve, or maintain, health and wellness **[19]**. The company offers genetic testing to physicians for their patients to support treatment of a variety of health conditions. The test menu ranges from somatic and hereditary cancer, including BRCA1 and BRCA2, to pharmacogenomics testing for well-known drugs like Plavix, codeine, lamotrigine, to general health and wellness testing which includes information on a number of health conditions including type 1 and type 2 diabetes and hypertension.

The Pathway Genomics's program with IBM Watson is the first of its kind to merge artificial intelligence and deep learning with precision medicine, applicable to both consumers and providers **[19]**. Consumers will be able to ask the Pathway Panorama app questions to gain insights and options powered by the cognitive computing capacities of Watson, based on their own wellness-related genes, wearable data, and other related wellness information, like emotional, physical and social well-being. The new mobile app will be designed to call upon Watson's unique ability to uncover insights by understanding the complexities of human language, referencing millions of pages of healthcare data from medical journals and clinic trial data within seconds. The data will be combined with information about

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the individual's lifestyle and wellness-related biomarker data, to provide personalized options, helping the user and their physician make informed decisions about living a healthier life.
Panorama will also routinely monitor a user's health and wellness information, and ping the user with any new relevant recommendations. For example, a consumer will be able to ask the Pathway Panorama app questions based on their DNA, like "How much exercise should I do today?" to "How much coffee can I drink on Monday?". The cognitive app answers and provides options based on the millions of healthcare-related evidence-based data, provided by Pathway Genomics, ingested by Watson and on the individual's biomarker, vital signs (wearables), DNA, electronic health records, and other information.

2.4 ADVANCED MATERIALS

Features

Advanced materials, also known as nanotechnology, can be defined as any use or manipulation of materials with features at a scale of less than 100 nanometers (roughly molecular scale).

A new revolution in materials has been taking shape in research laboratories around the world during the past few decades. These advances include the so-called smart materials that are self-healing or self-cleaning, memory metals that can revert to their original shapes, piezoelectric ceramics and crystals that turn pressure into energy, and nanomaterials.

How It Will Transform Companies and Society

Nanomaterials could have wide applications across healthcare, electronics, composites, solar cells, water desalination and filtration, chemicals, and catalysts **[7]**. Over the coming decade, the most important application of advanced nanomaterials could be the use of nanoparticles to create new-targeted treatments for cancer. In the near term, medicine could be the most promising area for adoption of advanced nanomaterials **[3]**.

At the society level, it is possible that, in the coming decade, nano-based materials and processes could help meet needs in medicine and perhaps see adoption in electronic products, such as displays. Medical diagnostics and treatments enabled by graphene, carbon nanotubes, quantum dots, gold nanoparticles, or biological nanomaterials such as liposomes and peptides, could save and extend many lives **[3, 7]**.

Technology and Market Maturity

In terms of the technology development stage, nanotechnology is often viewed as overhyped, as after many years it is delivering more promise than visible progress. Over the coming decade, the full potential of advanced nanomaterials may only begin to be felt, but these materials will likely continue to attract considerable interest and R&D investment **[7]**.

Regarding the market development stage, graphene for example, which is composed of one-atom-thick sheets of carbon hexagons, is being produced today, but only in limited quantities and at high cost. When this material can be mass-produced cost-effectively, its impact could be quite disruptive **[7, 20]**.

Expected Impact on Economy and Jobs

Despite the difficulties of large-scale production, it is expected that the global market for graphene will grow rapidly in the coming decade, though estimates range widely. The nanotechnology-enabled drug delivery market is expected to grow to €136 billion by 2021, with liposomes and gold nanoparticles accounting for 45% of this market **[20]**. The application of advanced nanomaterials for medical purposes has relatively high potential by 2025. For applications in medicine, specifically drug delivery for cancer patients, advanced nanomaterials could have a potential economic impact of €150 billion to €500 billion annually, by 2025 **[3]**.

Legislation and Regulation Issues

Considering that advanced materials may have a significant effect on the lives of billions around the world, legislation and public bodies must be configured to deal with the technology. Policy makers, for example, will need to address unanswered questions regarding the safety of nanomaterials **[7]**. Serious studies need to be conducted to identify any environmental and health risks posed by nanomaterials. Business leaders and entrepreneurs, particularly in healthcare, manufacturing, and electronics, should consider how these materials could be used to create new products or improve existing ones, and invest accordingly. Meanwhile, policy makers and regulators will need to address questions regarding the safety of nanomaterials.

Enablers and Hindrances

One of the hindrances to the evolution of the technology, in medicine for example, is whether specific nano-based drugs can be successfully developed and approved at reasonable cost or not **[20]**. Another important issue is that for advanced nanomaterials to deliver their full potential through 2025 and beyond, reliable and far less expensive methods will have to be developed for producing substances such as graphene, carbon nanotubes, and quantum dots in high volumes **[3]**. There is also a range of regulatory issues that will need to be resolved before widespread adoption is possible. Some nanomaterials can have high toxicity and could cause environmental damage, and many remain untested **[3]**. Regulations will be needed to guide nanomaterial use, not only in medicine, but also in other applications in which the material is not encapsulated, and rely on anticipated profound assessments involving all relevant stakeholders.

Nanofibers multiple domain use

Nanofibers are engineered textiles defined as fibers with diameters less than 500nm. Researchers around the globe are developing new uses for nanofibers in the broadest imaginable range of applications. Nanofibers often become a unique component of materials integrated deep inside of finished products. Nanofiber materials are used in an array of end products.

In medicine, nanofiber layers produced from biopolymers (chitosan, gelatine, collagen, polykaprolakton, etc., or combinations of these materials) can be used as a wound dressing for significant support of the wound healing process. When using nanofiber material on contaminated wounds, it is possible to add antibacterial material and drugs to the nanofiber structure. Granulation and re-epithelialisation of new dermal tissue can be enhanced by adding a growth factor, and other materials which support proliferation of dermal tissue. The wound can be covered by a single nanofiber layer or it is possible to incorporate a nanofiber layer onto other carriers and cover the wound with this composite material.

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In the apparel industry, for several years, waterproof breathable fabrics have been developed for use in garments to provide protection to the human body. The final properties of that fabric are defined by all of the materials used in the assembly of the composed material and by its after treatment. Membrane technologies and advanced polymers and materials have been developed to meet specific performance criteria for outdoor activities as well as occupational and industrial uses. Nanofibers can be used for a variety of apparel applications where their unique properties contribute to product functionality. Those properties include high surface area, small fiber diameter, potential to incorporate active chemistry, filtration properties, layer thinness, high permeability, and low basis weight.

Inorganic materials are used in many common applications and surround us in everyday life. Inorganic material in nanofiber form may offer the same or even better performance. The nanofibers are composed of ceramic or metal oxides. Its manufacturing process differs from the manufacture of organic nanofibers. The inorganic nanofibers are produced in bulk and require additional processing or calcinations to remove organic compounds from the material. The main applications for inorganic nanofiber usage are catalysis (e.g. photocatalysis), electrode materials and sensors nanocomposites (increasing of mechanical properties, electric and magnetic properties etc.).

2.5 ENERGY

2.5.1 Energy Storage

Features

New Energy Storage refers to devices or systems (including batteries) that convert electricity into a form that can be stored and converted back into electrical energy for later use, providing energy on demand. This ability to store energy for later use is the key characteristic of Energy Storage technologies **[7]**. Although this technology is not new *per se*, in the last few years, the combination of new materials for batteries – that sustain more energy capacity and a radical reduction of price (minus 70% in the last 7 years **[60]**) – with the use of advanced smart grids enabled by IT, and decentralized energy sourcing, has raised this technology to the level of disruption.

It has been used mostly in the energy and transportation sectors. With growing energy demand and growing concerns over CO_2 emissions and climate change, these two sectors are beginning to add more sustainable energy sources and, in both sectors, these efforts rely on Energy Storage.

How It Will Transform Companies and Society

Advanced batteries may impact the society both in advanced and developing economies **[3]**. In advanced economies and in the fastest-growing developing economies, the value of Energy Storage could be the ability to make Electric Vehicles (EV) competitive with cars that rely solely on internal-combustion engines. In the poorest developing economies, advanced batteries can provide millions of people with access to electricity, enabling them to connect to the digital world and join the global economy. Energy storage could also help bring electricity to remote areas in developing countries and boost the efficiency and quality of the electric grid, while helping to reduce CO_2 emissions.

The Energy Storage is disrupting the way people and companies relate to energy, as they can become both consumers and producers of energy, store energy to use when necessary or when it is cheaper than available energy sources, or sell it to other consumers through the infrastructure of smart grids **[61]**. Decentralized energy production, particularly using renewable sources like Photo Voltaic (PV) and Wind at homes and companies, will change energy utilities' position in the energy market, since individuals or corporate consumers can produce and store energy, along with selling to the grid, currently at a fixed price, and in the future to anyone who is willing to pay the price according to demand and supply dynamics.

Technology and Market Maturity

Although many Energy Storage solutions are still in the developmental stage and dependent on investments in basic science research, the technology is advancing rapidly and being applied in new ways, creating significant potential for impact and disruption **[60, 61]**. However, there are technologies such as Compressed Air Energy Storage (CAES), which is fairly mature, useful for utility grid applications. Still, utilities, regulators and private industry have begun exploring how battery-based Energy Storage can provide value to the electricity grid, at scale. However, the exact location of Energy Storage deployment, in the electricity system, is determinant to assess the impact of the value created by the technology. **[61]**.

Expected Impact on Economy and Jobs

In terms of the market development stage, the lithium ion (Li-ion) batteries, which are widely used in consumer electronic devices such as laptop, PCs, as well as in electric and plug-in hybrid vehicles, are expected to double in the next four years to €24 billion in global revenue **[3]**.

The potential economic impact of improved Energy Storage could be between €90 billion to €635 billion per year, by 2025 **[3]**. This value could arise from three primary applications: electric and hybrid vehicles (approximately €20 billion to €415 billion annually), distributed energy (between €25 billion and €150 billion in 2025), and utility grid storage (€45 billion to €70 billion annually).

Legislation and Regulation Issues

There are also concerns regarding how legislation and public bodies are configured to deal with the technology. Governments and research institutions are funding and conducting Energy Storage research, but storage solution providers that are not involved in research will need to keep abreast of how battery component technologies and manufacturing processes are evolving and build flexibility into their manufacturing processes, in order to be able to embrace emerging innovations. Utilities face both risks and opportunities due to advanced Energy Storage. While Energy Storage may help to improve the quality, reliability, and efficiency of the electricity supply, other uses could affect overall demand, both positively and negatively. Policy makers will play an important role in determining how much impact Energy Storage technologies have. Utility regulation should be reviewed to see whether there are incentives or disincentives for investment in grid storage and other relevant applications. Introduction of Renewable Energy quotas could also promote investment in Energy Storage. Portugal has been in the forefront of providing an adequate regulatory framework for the use of energy for mobility purposes, along with creating incentives for private and public agents to engage in the use of electric vehicles **[62]**. Results have been quite encouraging, with a spike in sales of EV, demonstrating the importance of the right regulatory, public and private incentives. Moreover, new financing models like leasing or outcome-based contracts are leveraging the adoption of Energy Storage-based solutions.

Enablers and Hindrances

There are also enablers and hindrances to the evolution of the technology. For example, for the full economic impact of advanced Energy Storage to be realized, storage technology will need to reach cost levels that meet those of existing alternatives and higher performance levels. Electric vehicles may also have to become less expensive to purchase and own, since the majority of new car sales in 2025 could be in developing markets **[3]**. In addition, there will need to be adequate infrastructure in the form of recharging stations. In grid applications, there are obstacles to advanced storage options beyond technology cost and performance. Regulatory policy is also critical. Regulations can prevent Energy Storage solutions from competing with generation assets (such as gas-powered plants), for frequency regulation and peak load generation, and prevent batteries from being employed beyond single-use applications.

The home Energy Storage new market

Driven by the explosion of residential solar power, the market for home Energy Storage is becoming of high interest. Seeking to expand its business beyond electric vehicles, Tesla Motors sells stationary batteries for residential, commercial, and utility use under a new brand, Tesla Energy **[21]**. Tesla is launching the home battery business, partly because it's already making vehicle batteries – and, as a result, it can benefit from the economies of scale that come from making both. Another reason is that the market for storage is expected to grow alongside the use of solar power.
Tesla's residential battery, called Powerwall, comes as 6.4 kilowatt-hour battery system that costs €3,000. Powerall is being promoted as having sufficient Energy Storage capacity to power most homes during the evening using electricity generated by solar panels during the day. **[22]**.

More players are entering in this market. A company called SimpliPhi Power has unveiled a lightweight battery system for homes and small businesses that offers a longer life span than other lithium-ion batteries and doesn't require expensive cooling and ventilation systems **[23]**. SimpliPhi's bid comes a few weeks after another Energy Storage provider, Orison, released its design for a small plug-and-play battery system that, unlike the SimpliPhi and Powerwall options, does not require elaborate installation or permits for a home or small commercial setting **[24]**. Its innovation is centered on the batteries' controls and communication systems: simply plugged into a wall socket, the battery enables a bidirectional flow of electricity, charging itself when power is flowing and sending power into the home circuits when it is not.

The growing popularity of residential solar panels is increasing interest in batteries that could store electricity from those installations. In the future, such storage systems could benefit homeowners, by giving them more control over how and when they obtain the power they need, while helping utilities by shifting demand to off-peak hours and smoothing out the load on the system. Home Energy Storage will make more sense in the years to come. Residential and commercial solar-plus-storage systems will offer a clear cost advantage over electricity from the grid.

2.5.2 Renewable Energy

Features

Renewable Energy is the generation of electricity and heat from renewable sources with reduced harmful climate impact. The key characteristic of renewable energies is that they are derived from a source that is continuously replenished, such as the sun, a river, wind, or the thermal power of the world's oceans. Renewable Energy can be used for different purposes. For example, solar panels can be used in small arrays to power a single building or home, or deployed in massive solar "farms" that feed into the power grid **[25]**. Like Energy Storage, Renewable Energy is not new *per se*, but in the last 7 years – with a significant price decrease in production costs (Land Wind Power minus 40%; Distributed Photovoltaic minus 50%; Utility Photovoltaic minus 60% **[60]**), and the deployment of smart grids enabled by IT infrastructure – it has become a significant game changer in the energy market. As an emergent Renewable Energy source, biomolecules are starting to be used by Amrys and Total for jet fuel, outperforming conventional petroleum-derived fuel in a range of performance metrics, including fit for purpose and greenhouse gas emission reduction potential, without compromising on performance quality.

How It Will Transform Companies and Society

Solar and wind power could generate enormous benefits, mainly for businesses that provide or consume energy, as well as consumers and society. Greater demand for renewables, for example, could provide opportunities for technology providers and suppliers of ancillary equipment **[3]**. Greater availability of renewables also creates opportunities for companies to set up more environmentally responsible operations **[7]**. Suppliers of fossil fuels are already being affected by the growth of renewables, which could curb demand for their products. Moreover, many more fossil fuel traditionally-based energy production companies, like EDP or Chevron, are changing their strategic position in the market, becoming also producers of Renewable Energy. Fossil fuel producers are facing new realities with governments imposing taxes, such as carbon taxes, and other regulatory instruments for reducing pollution and carbon emissions that add to their costs, and thus making these traditional source of energy less competitive.

At the society level, consumers may not realize direct economic benefits from Renewable Energy, since solar and wind power used by their utility providers may not cut their electric bills. But reducing fossil fuel emissions can have direct health effects, reducing the incidence of respiratory diseases and improving overall health through cleaner air, a need that is increasingly pressing in many rapidly developing nations. This will have a significant impact, for example, on China that is currently facing a serious problem related to fossil fuel emissions of its factories **[26]**.

Technology and Market Maturity

Further advances in solar and wind power technologies are under way. For example, thin film cells, which are made from compounds like cadmium telluride, copper indium gallium arsenide (CIGS) or amorphous silicon (A-Si), are being developed for PV use **[3]**. These advances reduce the amount of material used in creating solar cells and can be "printed" on flexible surfaces, potentially reducing cost and increasing ease of application.

The market for Renewable Energy in the EU and US continues to grow rapidly alongside natural gas, as an increasing source of power generation **[7]**. Solar cell technology is also progressing particularly rapidly. Renewable Energy sources such as solar and wind are increasingly being adopted at scale in advanced economies. Even more importantly, China, India and other emerging economies have aggressive plans for solar and wind adoption, that could enable further rapid economic growth while mitigating growing pollution concerns **[25]**. Recently, State Grid from China – and main shareholder of REN – has unveiled plans to deploy a long-range network for transportation of Renewable Energy (wind and solar) from Asia to Europe, Africa and the Americas. This long-range grid will imply also the development of storage capacity for improving energy transmission from long distances. The deployment of these type of networks will have a tremendous impact on the ability to secure sources of Renewable Energy continuously in time, and at an affordable cost, by consumers **[63]**.

Expected Impact on Economy and Jobs

Solar and wind power could represent 15 to 16% of global electricity generation in 2025, up from only 2% in 2013 **[3]**. The incremental economic impact of this growth could be €165 billion to €275 billion annually, by 2025. Of this, €145 billion to €155 billion could be the direct value added to the world economy from this power, less the cost of subsidies. The remaining €20 billion to €120 billion per year reflects the possible value of the reduction in CO_2 emissions.

Legislation and Regulation Issues

Policy makers and regulators must also be configured to deal with the technology, which will also require intergovernmental cooperation, as well as cooperation with private agents. For example, to accommodate the rising share of solar and wind power in grids, utilities will need to invest in infrastructure improvements, to manage increased intermittency and bi-directionality (caused by feeds from distributed solar power) on their grids **[3]**. In some countries, like the US, the UK or Portugal, these investments have been occurring, though the coverage level is not yet complete. Governments will have to weigh the benefits of adopting more solar and wind power against the costs of maintaining subsidies. With some Renewable Energy sources becoming mature and their production costs becoming lower than traditional energy sources, governments are shifting subsidies to more immature renewable sources **[62]**. To meet the global target of less than a two-degree rise in temperature by 2050, policy makers may have to consider more aggressive policies related to greenhouse gas emissions, and make further concessions towards more environmentally sustainable uses of energy **[27]**.

Enablers and Hindrances

Renewable Energy holds a simple, but tantalizing promise. Such promise has been elusive until a few years ago, because of the relatively high cost of Renewable Energy sources, such as solar and wind, compared with fossil fuels, such as coal, oil and gas **[25]**. This reality is changing, and in many countries the production costs of wind and solar energy has considerably decreased, becoming competitive with traditional fossil energy production which, contrary to public opinion, has often production subsidies.

An overarching question for the growth of wind and solar power is whether the environmental concerns of citizens will be sufficiently powerful to motivate governments to continue to subsidize renewables – even if fossil fuel supplies rise and prices fall **[26]** – and start eliminating subsidies from the traditional sources.

Technological advances that further reduce the costs of Renewable Energy generation will be important enablers of adoption **[28]**. Another factor for renewables, at least in places such as the US and Canada, could be the impact of unconventional sources such as shale oil and gas. An increase in the gas and oil supply could drive down prices, as well as reduce emissions, by replacing coal for natural gas, thereby reducing the economic and social rationale for adoption of renewables.

Microgeneration, smart grids and storage

As environmental pressure mounts, people can take positive action to cut carbon emissions and reduce global warming from their own home. Microgeneration systems can be used to provide heat and power for homes, including terraced or detached houses, flats and bungalows. Solar thermal, ground or air-sourced heat pumps and biomass-fuelled boilers can provide water or space heating, all from renewable sources. Solar photovoltaics can be installed at home to provide electricity.

In Portugal, the power of the sun can be harnessed via a roof-mounted solar thermal unit to reduce water heating costs by up to 60% over the course of a year, regardless of one's existing heating system. A microgeneration solar water heating system will reduce one's impact on the environment.
For example, a typical solar thermal installation can reduce a household's carbon dioxide emissions by over one ton per year. Most of solar thermal installations also use a solar-powered pump and control system, and are therefore truly 100% green.

However, the future of microgeneration will be much dependent on home storage capacity. Its economics, as wel as its ability to truly deploy smart grids, enter in a competitive energy distribution market. Incentives for the later are fundamental, as is a change of business models by energy distributors that will make them invest in modern infrastructures of metering and thus enabling true smart meters to be deployed.

3. Catching the Wave

This chapter describes how the Portuguese economy, companies and society are likely to be affected by the Technology Wave. It looks at how current technology disruption may impact the main economic sectors, and how society should prepare to deal with the forthcoming changes.

3.1 THE GRAPES OF WRATH

This section looks at how current technology disruption may impact Portugal's main economic sectors, both in size and growing trend. It examines and cross-checks the meta-analysis findings with results found in reports of the Instituto Nacional de Estatística (INE) on Portuguese economic sectors, comparing both value creation and employment.

3.1.1 Expected impact on leading export sectors

According to PORDATA **[30]**, in 2014, Portugal exported a total of €70.964,0 million around 40,91% of the national Gross Domestic Product (GDP) making it the 17th largest exporter in Europe. Between 2008 and 2013, Portugal's exports increased at an annual rate of 5,0%, from €55.801,8 million in 2008 to €67.353,2 million in 2013. In 2014, the top five leading export sectors were Machinery and Appliances, which represented 9,83% of the total exports, followed by Motor Vehicles and Other Transportation Equipment (7,39%), Mineral Fuels (5,77%), Common Metals (5,46%), Plastic and Rubber Products (4,87%) **[31]**. These are the top leading sectors since 2010. Following, **Figure 1** shows main export sectors of goods in 2014 and **Figure 2** the average annual growth.

Figure 1 – Portuguese Exports of goods in 2014 [31]

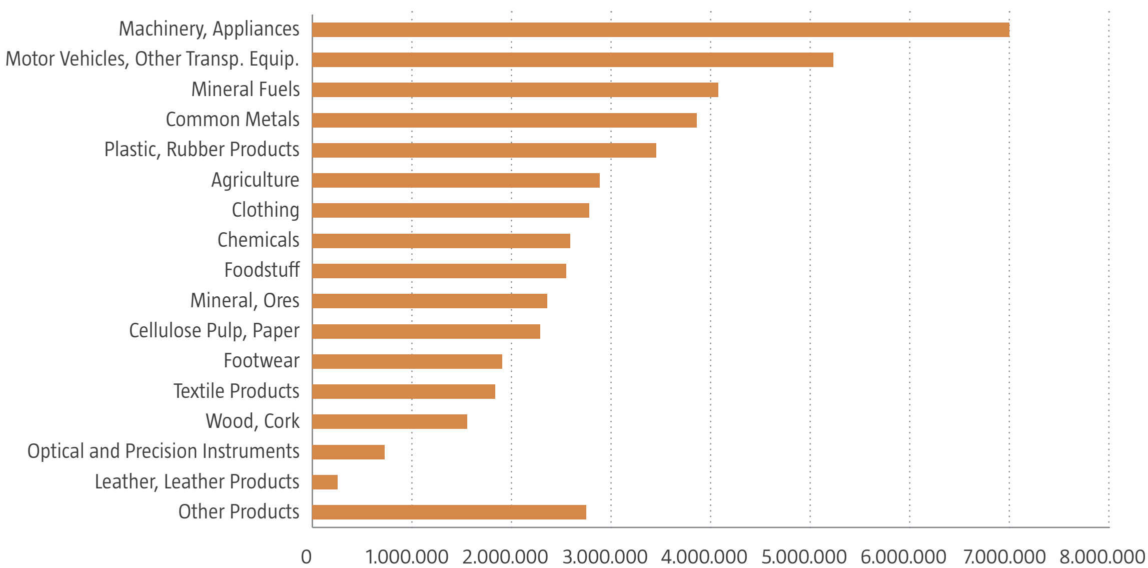
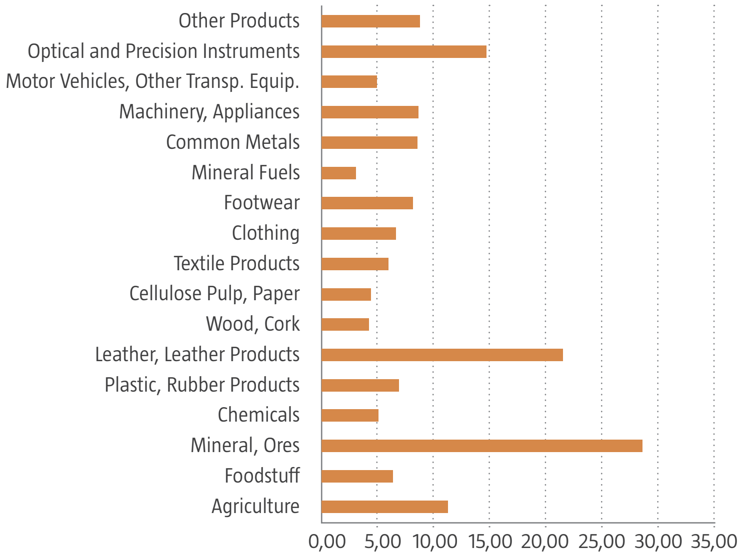


Figure 2 – Average Annual Growth of Exporting Sectors



The leading export sectors likely to experience the greatest impact resulting from disruptive technologies in the next five to ten years are Motor Vehicles and Other Transportation; Mineral Fuels; Plastic and Rubber Products; Machinery and Appliances; Transportation and Storage; Production and Distribution of Electricity, Gas, Heat and Cool Air.

Regarding the Internet of Things technology, significant impacts will be achieved in Transportation and Storage. Adding intelligent sensors to automobiles to prevent crashes, along with the potential of Autonomous Vehicles to reduce the number of traffic accidents, could significantly reduce the number of deaths and injuries on the roads of Portugal. This may also impact the insurance industry, as the reduced level of traffic accidents and insurance claims could lead to a decrease in premiums. If so, insurance companies may need to redesign their business models in order to maintain competitiveness and support Autonomous Vehicles. Portuguese Oporto-based startup Veniam is an excellent example of the deployment of Internet of Things technology, that simultaneously creates intelligent mobility, and monitors environmental data. With over 600 vehicles (from buses, taxis and garbage collection lorries), they simultaneously provide mobile Internet and a set of applications that can be used to monitor traffic, air quality, etc. The success of this city-wide deployment, and the company's internationalization with projects around the world, led to a recent VC investment of €20 million **[64]**.

The adoption of intelligent sensors and Autonomous Vehicles could also contribute to decrease the time lost to congestion on main roads. This could contribute to improve the manufacturing logistic systems and improve the lead time in the Portuguese supply chains, which may impact several export sectors. At the environmental level, a significant reduction of CO_2 emissions could also be achieved. On the other hand, there is also negative impact to be considered, as taxi and truck drivers may need to convert their jobs, if the adoption of Autonomous Vehicles becomes widely accepted in Portugal and Europe.

Internet of Things, Cognitive Computing and Advanced Robots may also have a significant impact on Portuguese manufacturing companies. Connecting the various objects through Internet of Things, using Advanced Robots to carry out many routine tasks so far performed by humans, and using sophisticated analytic tools to perform tasks that are currently performed by knowledge workers, will contribute to significant productivity gains and cost reduction in companies operating in manufacturing industries such as Automotive, Aeronautical and Textiles. The negative impact could be the number of jobs that may be replaced by the adoption of Advanced Robots and Cognitive Computing. For example, in supply chains such as Volkswagen AutoEuropa – which mobilizes a workforce of about 40,000 people –, many jobs (including high-qualified ones such as logistic and production planning) can be fully automated. As reiterated before, while automation will lead to a reconversion of the existing workforce, emergent technologies will also create new jobs, though their profile is still unclear. The Portuguese textile sector is a very good example on how to evolve, as global competition changes. Today, Portuguese textile companies are recognized as leading innovators, using the most advanced technologies such as nanofabrics and advanced robots in the production line. TMG Automotive is recognized as a leading supplier to renowned brands like BMW, Mercedes, Volvo, Daimler, having made the shift from being a traditional low cost subcontractor to become a strong brand associated with innovation in products and processes in their market niche **[65]**. It also shows how incumbents in a mature market can reinvent themselves through technology and people, and become leaders in their markets. Regarding Advanced Robotics, companies like Introsys **[66]** and Motofil Robotics **[67]** are also incumbent companies which have been demonstrating how they can compete with the best, in class robot vendors, by supplying advanced robot systems to some of the leading manufacturing plants in Europe, in various industrial sectors like automotive, textile or retailing. The capabilities and competitiveness of these companies in a highly competitive and sophisticated market, where companies can only survive if they master the latest technology, provide a good example of how Portuguese companies, managers, engineers and the workforce in general, can succeed globally while being based in Portugal.

In the Plastic and Rubber Products sector, 3D Printing/Additive Manufacturing may create significant disruption in the way plastic goods are produced. On the positive side, there is potential to increase productivity by reducing plastic wastage material. This will benefit consumers, as those products could become cheaper. The Automotive and Aeronautical sectors may also be affected as the plastic parts could be produced, only if required, using Additive Printing. This will contribute to decrease the inventory cost of obsolete products, affecting the recycling industry, that will have a less amount of plastic waste to recycle. BeeVeryCreative is a Portuguse company that manufactures 3D Printers and provides also 3D Printing services and 3D Modeling, both for home consumers and to professional and industrial settings. With its product BEETHEFIRST, the company has been awarded the "Best of Plug'n Play 3D Printers" in the 3D Hubs 2016 Printer guide, based on 5 350 reviews from the 3D Hubs community, and follows a similar prize in the 2015 edition **[68]**. Once again, this is an excellent example of the capability of the Portuguese companies to be internationally recognized in a very sophisticated and competitive market.

Energy Storage and Renewable Energy could have a significant impact on sectors such as Mineral Fuels, Production and Distribution of Electricity, Gas, Heat and Cool Air, and Transportation. The adoption of those technologies could have a negative impact on the export and internal consumption of mineral fuels, reducing the turnover generated by this sector. But those technologies can also lower the prices of electricity, oil and gas, benefiting not only transportation and manufacturing companies, making them more competitive, but also domestic consumers. This will probably contribute to decrease the price of travelling, and as a result, improve the turnover of the Transportation sector as more people will likely travel. On the other hand, Portuguese companies have the potential to become net exporters of Renewable Energy.

3.1.2 Expected impact on emergent export sectors and other relevant sectors

After examining the results of the INE's reports on the economy sectors, both in exports and turnover, we concluded that the emergent sectors in Portugal are High-tech, Healthcare, Information and Communication Technology (ICT), Computer Programming, Consultancy and Related Activities and Renewable Energy.

High-tech is the sector that will experience the most disruption, as all disruptive technologies are coming from this sector. The Portuguese companies operating in this field will have their business models increasingly disrupted given the rapid introduction of new technologies. There are many opportunities in this sector regarding the development of sophisticated analytical tools that can be used to perform most of the tasks, so far carried out by knowledge workers. The Portuguese technological companies and entrepreneurs have a great chance to boost their business, exports and turnover. In the last 5 years, a number of digital startups have successfully emerged in the global startup scene with innovative products and services, establishing themselves in a highly dynamic and competitive market. Feedzai is a company founded by Coimbra's engineers that applies artificial intelligence and machine learning algorithms to analyse corporate risks **[69]**. The company has seen a tremendous increase in products and services sales, mainly in global markets and particularly from financial companies that apply these sophisticated algorithms in real time fraud detection of credit cards or other financial transactions. Another highly successful company is Unbabel that uses artificial intelligence algorithms and crowdsourcing for document/written texts translation in multiple languages, primarily focusing on corporate clients **[70]**. The key to the company's success is the ability to provide very fast and excellent translation at low cost, combining machine and human processing. More recently, Talkdesk, a startup founded by university students in Lisbon, developed a disruptive service and business model, by setting up a contact center targeted at SMEs at a low cost and a plug 'n play approach, using cloud computing technology. All these companies have been able to successfully secure funding from Portuguese and international VCs and to expand internationally. What all of them have in common is the use of the latest disruptive technology to create new businesses, services and products that reached global, highly sophisticated and competitive markets. Portugal has also good, and often unknown, examples of incumbent firms that have gained an international dimension. TimWe, which was founded in 2002 to provide services for distributing digital entertainment content to European operators in the perspective of generic brands, has evolved over the years to become a global provider of services for mobile and web-based services, ranging from mobile digital marketing and sales, to portals, designing, delivering and managing end-to-end solutions to companies, operators, governments and consumers **[71]**. They reached a staggering revenue of €281 million in 2015, of which 98% from foreign markets. Another good example is Farfetch, a London-based luxury fashion e-commerce platform founded by a Portuguese, 10 years ago (not so much a startup as is often referred). With its logistics operations based in Portugal, it is being positioned as the first Portuguese Unicorn (company with over 1 billion euros valuation), and one of the most promising European digital companies **[72]**.

There is also a great opportunity for new job creation in the application of High-tech in traditional sectors. For example, Internet of Things, Cloud Computing or 3D Printing will have significant impact on the Healthcare sector. Internet of Things can be used to monitor patients in hospitals, freeing doctors to perform other tasks. In the longer term, 3D Printing could be used to produce living organs, contributing to save many lives and improve the mobility of many disabled people in Portugal. Hospital managers could also use it to print healthcare equipment, thus minimizing the inventory of these products. The Portuguese startup LineHealth is a very good example of the application of Internet of Things, Mobile Computing and Cloud Computing in the healthcare sector, by developing a smart pill dispenser, getting patients engaged and tracking their interactions, while monitoring and controlling their pills intake. Although the company is still in its early stages, it is supported by global players like Bayer HealthCare, NeuroTexas Institute and IC2 Institute from the US. The company plans to start making revenues in 2017.

Advanced Robots, Genomics and Advanced Materials also have potential to disrupt the Portuguese Healthcare sector. Advanced Robots could be used, for example, as co-workers helping doctors in surgery and prosthetics. This would increase the productivity of doctors, save and improve the quality of lives. Genomics will be used in Healthcare to better identify and diagnose people with heart disease, diabetes or other relevant diseases. Genomic sequencing can also decrease the death rate during immunology and transplant medicine, on people with infectious diseases. In the field of Genomics, Portuguese startups are also paving the way forward. A good example is Coimbra Genomics, that has developed ELSIE, a clinical decision support system based on a patient's whole genome sequence. ELSIE is a simple-to-use platform that helps doctors and patients together to make more personalized diagnoses and prognoses, as well as adjust treatments and prescriptions based on the patients' genomic information. ELSIE offers a continuously growing list of Genome Queries for a diverse panel of diseases, conditions and therapeutic agents, which is becoming a competitive advantage in a market focused on very specific conditions.

Energy Storage and Renewable Energy are the technologies with the highest probability to disrupt the Energy sector, particularly the Renewable Energy sector.
According to INE and the Directorate General for Energy and Geology (DGEG), the contribution of Renewable Energy to the final consumption of electricity increased from 31,88% in 2008 to 44,68% in 2012 and 62% in 2014. This helps Portugal to be increasingly independent from fuels and contributes to reduce CO_2 emissions.

Portugal currently has a total production capacity of 12,14 GW in renewable energies and plans to upgrade this capacity to 15,82 GW until 2020, according to the National Energy Strategy 2020.

An example of the economic impact of this technology is the ENEOP Consortium - Eólicas de Portugal, S.A., which recently celebrated the completion of the tender for the first and biggest exploitation license at 1 200 MW in Portugal. As a result, the first industrial cluster in Portugal for wind energy was developed (and the largest consortium in the EU in installed power capacity in a single country), representing an investment of approximately €1 300 million, a Gross Value Added of 300 million per year, and the development of new export products. Since 2010, a total capacity of 1 335 MW was installed in more than 50 wind farms all over the country, 5,8 million tons of CO_2 emissions were avoided and more than 1 800 skilled jobs were created within the 29 companies of the cluster. After the completion of the project, the companies continue to use the production capacities installed in Portugal for export projects, based on the output of the several industrial units established in the country.

This commitment with clean energies is boosting investments in R&D, and developing new and innovative industries and business models. Two Portuguese universities, along with some of the finest companies in the ceramic industry, developed the "Solar Tiles Project" aiming to produce electricity from solar energy using simple roof solar tiles instead of the traditional solar panels. Copérnico, a Portuguese citizen-owned initiative for small-scale Renewable Energy production, was recently nominated for the EU Sustainable Energy Awards 2016. These, and several other investments, should be contributing to an electricity price fall, benefiting domestic consumers and companies in different industries. Also, the new EU 2030 climate and energy framework not only established new targets for CO_2 emissions, Renewable Energy and energy efficiency, but it also established binding targets on electricity interconnections (10% by 2020 and 15% by 2030). This new approach will foster Renewable Energy production at EU level. Therefore, Portugal will benefit from this new approach to boost new projects and to export Renewable Energy electricity (mainly solar) to central and eastern European countries. This represents the 3.0 stage of the Renewable Energy cluster in Portugal.

3.2 CREATING A BRIGHTER FUTURE

European and Portuguese businesses are not transforming rapidly enough in face of the T-Wave. Despite the obvious benefits, European and Portuguese businesses, especially smaller ones, have been slow to change. Examples described in the section above may claim variations across economic sectors, but multiple studies have diagnosed problems in leadership, trust, competences and skills.

Successful technological transformation is not embedded in existing businesses. It must be an integral part of change in processes, organisational structures, the workforce and the culture. The leaders of such change need confidence and know-how. While signals of the importance of technological transformation are emerging, the vast majority of the public and political discourse still focus on the risks and the negative aspects. There is an obvious concern regarding competitiveness, employment and jobs. If we look at the impact of the mechanisation of agriculture, the computerisation of the office, the automation of the shop floor in manufacturing, and more recently of the Internet in services, it is normal to expect that current jobs will be affected by the new wave of digitalisation, cognitive computation, artificial intelligence and robotisation, along with higher productivity of genetic-related industries and energy efficient systems. Whereas this foreseeable impact has been identified, it has also been advocated that while many jobs will disappear or suffer transformations, many others will emerge in a refreshed economy. The Schumpeterian creative destruction movement is likely to still hold true.

The Technological Wave poses challenges to the competitiveness of companies, but these challenges are multifaceted, as pressure for acknowledging and embedding technologies in existing practices, processes, management and business relationships will increase. The bigger challenge will lie with the individuals within organizations. But the Technological Wave creates great opportunities as well, particularly to all the early adopters of the technology, both incumbents and entrepreneurs. The companies and individuals that are fast to adapt will enjoy first movers advantage, increasing efficiency, and reducing costs and time to market. They will be able to quickly analyze and understand the rapidly evolving requirements of clients, while leveraging the technology to create new services and products.

3.2.1 The I-Connected individual

Companies learn through people and people learn from their peers. Hence, business networks are increasingly valuable in times of change, as they become triggers and nests for innovation and change. Many new networks have been established for young innovative companies and there are many long-standing networks for existing businesses too. Yet, there have been limited opportunities for cross-fertilization of ideas between these two worlds of old (incumbents) and new businesses (entrepreneurs). This creates new opportunities: people and networks of existing businesses are a rich source of business of experiences for the new and innovative entrepreneurs and the two different worlds have a lot to learn from one another.

The creative class comprizes between 30%-40% of the workforce in the advanced nations, and includes scientists and technologists; artists; cultural creatives; and media workers, as well knowledge-based professionals in business, education and health-care **[32]**. The usually referred service class, larger than the creative class, is made up of lower-skill, lower-wage, routine service occupations in fields like healthcare support, food preparation and service, low-end retail, and office and administrative positions. The divide between these two main classes lies at the root of growing inequality and class division across, in advanced and developing nations alike. The traditional working class (which includes manufacturing) represents less than each of these classes, between 15%-20%.

Growth and prosperity under creative capitalism turns on a new model dependent on three factors: Technology, Talent, and Tolerance **[32]**. We have discussed in section two how technology may impact economy and society. Talent is present in two ways – by the share of the workforce in the creative class and the share of adults with tertiary education. In a world driven by fast technology change, the opportunity resides in people. The tolerance factor is relevant as well. A growing body of research finds that openness to diversity spurs economic development, while homogeneity stunts economic growth. Places that are open to new ideas and embrace diversity tend to attract creative people from around the globe, who provide an edge in generating the innovations and startup companies that create new industries. Tolerant places broaden their technology and talent capabilities, giving them an economic edge over less tolerant places.

The T-Wave is thus creating opportunities for more creative-based and service-based business models, where customer-orientation is an asset. John Maynard Keynes's frequently cited prediction of widespread technological unemployment "due to our discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour" **[33]** will have a dual reality. Digitalisation, Artificial Intelligence and Robotics are likely to have a significant impact on service jobs, as many of the traditional cognitive human-based jobs are being replaced by technology. However, the creative class is likely to gain from these technologies, leveraging the potential of the advances on Genomics, new materials and new energy technologies. Though new jobs are likely to emerge for the service class as well, these will be less relevant and with low added value, compared to the jobs created for the creative class.

As the pace of technological change increases exponentially, companies will need access to pools of talents with the adequate technical competences and skills. Studies point out how Europe and Portugal have a shortage of these technical competences and skills. There is a growing movement on human capital development, stressing the importance of carefully selecting and managing talents to improve companies' performance. While there has been substantial focus on talent, the approach often falls short when addressing the Technological Wave. The focus has been on companies' difficulty to effectively hire and develop people's competences and skills in the face of upcoming challenges posed by markets disruptions and the lack of adequate technical labour workforce.

But the real challenge lies in the leadership role that enables the transformation of the traditional manufacturing and service workforce in talents and creative jobs. Put another way, the most significant and paramount need for leaders of technological change is delivering talents, leveraging creative class networks, connecting people in existing businesses with innovative entrepreneurs and startup ecosystems, while fomenting a learning and open environment.

How digital is transforming tourism

Hospitality and tourism are some of the industries that are most affected by the digital T-Wave. Transportation and accommodation companies are among the first ones to utilize digital marketing techniques in their practices to engage communities and make sure their customers have the best possible away-from-home experiences. Before going on a trip, most people research about the place they are about to visit. Once they arrive at the destination, the search continues. The power of Wi-Fi allows travelers to use their devices anywhere and anytime, from the hotel room to coffee shops and touristic attractions. As a result, planning any trip becomes as easy as visiting a review website and choosing the next destination point. Facing competition from Airbnb and their local travel guides, large hotel chains are also recognizing the need to expand the range of their offering to deliver even more value to the customers. Hotels are introducing services that allow their customers to explore the neighborhoods they are staying at, by offering local travelling guides. The mobile site version allows travelers to see available content, even when they are not staying at one of the hotels. The guides provide maps, useful information about local attractions and restaurants, hotel overviews and a Facebook linked photo-sharing tool. Also, social media marketing, search engine marketing, email marketing, online advertising, for travel, tourism, hotel, resort and hospitality has become a key competence in these domains.
The use of mobile devices is also on the rise in the tourism industry. Additionally, it might be even more ground-breaking, since people use various devices to book their airplane tickets and hotel rooms. As a result, there is an emerging trend of mobile-only travel agencies. These companies offer travelers the ability to book tickets through downloadable mobile/ tablet-exclusive apps. Although currently, most of those services are focusing on tonight-only bookings made by travelers on the go, in the future we can expect to see an emergence of full-service mobile travelling agencies.

This led to the success of tourism, hospitality and transportation digital companies like Booking, TripAdvisor, Trivago, Skyscanner, that were created by creative entrepreneurs. The Fork is a Portuguese startup that was recently acquired by TripAdvisor and demonstrates how innovative ideas can succeed. Whether focused on increasing rankings and traffic, increasing social media fans and followers, building email lists, running a contest, or developing travel content and applications, a whole new set of creative digital savvy talents with travel and tourism internet marketing expertise have emerged and are today fundamental jobs for tourism/hospitality agents.

3.2.2 Can everyone T-Surf?

The T-Wave is expected to have a significant impact in several types of jobs, opening new horizons for much of the creative class, but also for the traditional working and services classes, as they adapt their skills and competences to new technologies. Indeed, those that have the adequate competences and skills to embrace the realm of technology, or are fast to acquire them, will find an exponential growth of opportunities to exploit their talent. Conversely, pure traditional working and service jobs that do not adapt fast enough to exploit the potential of the T-Wave, will have their employment base reduced.

There are two main types of competences and skills required to "surf" the Technological Wave (T-Surf): Technological Proficiency (T-Proficiency), which relate to technical knowledge in the scientific, engineering and technology domains; and Technological Leadership (T-Leadership) that refers to the soft competences and skills domain.

There are mixed signals from data regarding the T-Proficiency competences and skills in Portugal. Most indicators in this field reveal that the performance of people and systems in Portugal is poor. The worst indicator is the percentage of the population having completed tertiary education, or having attained at least upper secondary education, where Portugal is at the bottom of EU and OECD rankings **[34]**. Society indicators revealing Internet access, by population, perform poorly, placing Portugal at the bottom of rankings **[35]**. Well below the average of EU performance, is license and patent revenues from abroad, PCT patent applications in societal challenges, and private R&D investment **[36]**.

Although there is an overwhelming number of studies depicting these overall poor performances, which may pose a hinder for Portuguese talents to take advantage of the T-Wave, there is also hard evidence showing that several of these indicators have improved significantly over the last 10-15 years. For example, the recent OECD Pisa results revealed that Portugal has improved its average results in all categories, not only in Mathematical, Reading and Science scores, but also in Excellence results (top tier students) **[37]**. Moreover, several studies demonstrate that Portugal has also strengths to cope with upcoming technological challenges. In a recent OECD report, Portugal ranks 10th in the teaching of science, technology and industry **[38]**. While performing poorly on tertiary and upper secondary education, the production of PhD talents is aligned with the average of the EU, and the international scientific co-publications indicator is at the top of EU countries **[36]**. Indeed, these reports demonstrate that the scientific capacity and output has had a major improvement in the last 20 years in a range of fields from the life sciences and genomics, to computer science, robotics, energy and new materials. In many of the categories of the T-Wave, Portuguese talents are among the top referenced scientists.

There are further relevant indicators that may suggest that Portuguese society and economy, in general, and talent in particular, are better poised to leverage the T-Wave than some of the traditional indicators might suggest. And those indicators are more related with T-Leadership than with T-Proficiency. T-Leadership is recognized as a fundamental cornerstone in leveraging the T-Wave. T-Leadership is about boosting soft competences and skills needed to steer innovation processes within ecosystems and organizations. It is about promoting entrepreneurship in disrupting markets. These skills enable people to lead others to design business models and exploit key opportunities, making the best use of the T-Wave and delivering value to their organizations, in all levels of enterprise, from startups to the large corporations, both private and public.

There is a general recognition that it will be hard for companies to succeed in innovation without the ability to have talent focused on combining market opportunities with the technological proficiency that enables solutions to meet market needs. Corporate innovation is in itself in the midst of major changes, from traditional closed innovation systems to more open and entrepreneurial innovation ecosystems. Large corporations are starting to innovate, together with startups and acceleration programs in a mindset of innovation and entrepreneurship **[39]**. Moreover, innovation and entrepreneurial activity is focusing not only on technology, but on the combination of technology with new business models. As a result of these changes, innovation is becoming less institutionalized, more fluid and with greater cross-fertilization of scientific domains and market sectors.

While there is a public sense that Portuguese SMEs tend to be technological laggards, evidence shows that they have been consistently more innovative in products, processes, marketing and organization then the average of EU SMEs **[36]**. Although Portugal is classified only as a moderate innovator at the EU level, the few indicators that show the country is above European average mainly relate to SMEs innovation prowess.

To reinforce this perspective, and considering creativity as an increasingly significant cornerstone of innovation and economic progress for nations across the globe, the Global Creativity Index – that measures creative competitiveness and prosperity in 139 nations worldwide – holds Portugal in the global 23rd position, and 17th at the European level **[32]**. Creativity has a strong correlation with economic output, measured by GDP per capita; economic competitiveness is based on economic output, innovation, efficiency, and the overall business climate; and entrepreneurship is measured in the Global Entrepreneurship Index, a broad measure of entrepreneurial activity **[32]**.

The European Digital City Index of 2015 is aligned with the Global Creativity Index' results, positioning Lisbon in the 17th place among the 37 European major digital city ecosystems. When considering the capital cities alone, Lisbon is positioned in 12th place among the EU 28 **[40]**. Moreover, the authors of the report emphasize the 'buzz' around Lisbon, the growth of the startup scene and the city's low costs of living, and high quality of life, which, in their view, has attracted many, putting Lisbon on the map as an emerging startup hub in Europe. The authors anticipate that Europe will be hearing a lot more about Lisbon in the near future. In addition, Lisbon was awarded European Entrepreneurial Region (EER 2015) due to its initiatives and strategy to promote entrepreneurship and innovation in SMEs **[78]**.

The Digital entrepreneurship scene in Portugal – and Lisbon in particular – is an excellent example of the T-Leardership outcome. Since 2010, organisations like Startup Lisboa, Beta-i, and Fábrica de Startups in Lisbon; Instituto Pedro Nunes in Coimbra; UPTECT in Oporto; and Startup Braga in Braga, have done a tremendous amount of work to promote the emergence of a vibrant, international, and fashionable digital entrepreneurship ecosystem. Their work demonstrated that, with the right combination of soft competences and skills, it was possible to steer national and local public governing bodies, private promoters as sponsors, and attract international VCs and press like Bloomberg, Financial Times and CNN. Moreover, they were able to attract both local and international T-Proficient talents to Lisbon, Coimbra, Oporto and Braga, to deliver significant entrepreneurship activity and bootstrap successful startups. Startups like Feedzai, Unbabel, Talkdesk, Uniplaces, Veniam and several others are now scaling up and establishing themselves at the global level.

Hence, the role of T-Leadership is of paramount importance to the T-Wave. This has recently been recognized by the European Commission, which established, in February 2014, the Strategic Policy Forum on Digital Entrepreneurship, bringing together leaders from business, academia, international organizations, civil society and the public sector. Although focusing mainly on the digital transformation, the same premises can be considered for Genomics, new materials, or energy domains. The Strategic Policy Forum focuses on addressing the following strategic vectors: leadership and collaboration; build trust; better and more skills and support; better policies, rules and regulations. Regarding leadership and collaboration, the strategy stresses the need to demonstrate inspirational political leadership and to set national digital transformation targets. The focus is also placed on establishing new centres of digital transformation excellence and a pan-European network of such centres, while developing a European blueprint on the basis of shared experiences. The focus of the European Commission on leadership and collaboration for digital transformation is grounded on the belief that T-Proficiency, though important, will not be enough *per se* to drive the revolution of the second digital wave.

Portuguese Digital Ecosystem in the spotlight

The Portuguese startup scene has been reaching out to the world. In an article of 23rd of August 2015, *Forbes*, the world renowned business and finance magazine highlighted the relevance of the strong entrepreneurial spirit that has emerged in Portugal over the last few years **[42]**. Thanks to the potential of Portuguese startups and foreign investments, mostly from the US, *Forbes* highlights some of the best startups in Portugal, such as Talkdesk, Feedzai, Veniam, Line Health, and Unbabel. *Forbes* also recognizes the accelerator Lisbon Challenge as being among "the top five most active programmes in Europe". They also highlight the fact that many startups who have been through these programs have emerged and gone on to join the likes of TechStars, Y Combinator and Seedcamp. The article also acknowledged the government's support of entrepreneurship, with the launch of Portugal Ventures as a VC, and Startup Lisboa as a key incubator which has provided a further boost to the ecosystem.

Previously, on the 25th of March 2014, the *Financial Times* compared Lisbon to San Francisco, highlighting that the two cities share many physical attributes like the hills, cable cars and large red suspension bridges, while underlining that Lisbon is also keen to adopt the spirit of its new world counterpart as a global centre for startups **[43]**. The respected business and finance newspaper stressed that support for early-stage ventures is growing based on a cluster of incubator and acceleration programs that is up and running and recognized the good supply of engineering graduates from local universities.

More recently, Paddy Cosgrave, one of the founders of the Web Summit – the biggest digital startup event in Europe, which has changed its venue from Dublin to Lisbon starting 2016 – while visiting Startup Braga, was impressed by Braga's accomplishments in developing its digital ecosystems in such a short period of time **[82]**. He stated that Oporto's and Braga's developments in the startup scene will leverage the participation of Portuguese entrepreneurs in the global and highly competitive market, and will certainly benefit from the organization of the Web Summit in Lisbon.

Finally, Oporto has become a pioneering city for promoting the scale up of startups, through the creation of the Manifesto ScaleUp Porto. This initiative aims to become a catalyst for the creation of an innovation ecosystem, and a network of individuals and organizations that share the vision of a scale up program, making Oporto the leading city for the ScaleUp For Europe movement, an European-wide initiative focused on enhancing the importance cities can have in the ecosystem growth **[83]**.

3.2.3 Yes, I can T-Surf

Although the Portuguese economy is evolving positively, and signaling that recovery and labour markets are becoming more dynamic, with (slow) growth of GDP and unemployment levels decreasing, there are still some structural issues like severe talent mismatch. Long-term high unemployment is a major issue, but also is the gap between high premium wages in high-skill industries (e.g. creative class) and low skilled jobs (e.g. parts of the services and manufacturing industries). Moreover, the emigration of many talents in recent years will put pressure on Portuguese companies.

Despite these problems, one can argue that the T-Wave will continue to challenge and pressure each person individually, and people collectively, as players in the economy and the society as a whole. The question is then, "How can the individual self-adapt to the T-Wave?". There is no straightforward answer to the question, but there are hints as to how each individual shall consider his/her own adaptation process to fulfil his/her talent in the context of the T-Wave.

Talents are not inborn, they emerge in each individual, but are also dependent on external triggers. The absence of stimuli is often related with talent shadowing. Talents require time, hard work and a learning attitude, in a try and fail mode, and an entrepreneurial mind-set. But it is an illusion to think that the only thing that people need to release their talent is willpower. Although important, talent is contingent on three main elements **[44]**: Stimuli, Mentoring and Opportunities. The absence of these elements hinders talent emergence.

Stimuli

Although the entrepreneurial attitude, prowess and resilience are often part of one's genes, they are also contingent on the education, social environment (family, friends, colleagues), and economic context. Those factors help shape people's personalities over the years. Stimuli are thus extremely important for talent emergence in spite of the individuals' personalities.

Although stimuli are more effective in the early stages of childhood and teen ages, incentives may also greatly impact the talent development needed to embrace the T-Wave in adulthood. One of the major limitations to talent development is the risk of misperception that people cannot evolve overtime or are limited by their specific context and situation. Individuals should focus on a learning mindset and believe that they can grow, and develop their technological proficiency and leadership skills, even if we all are different and may follow disparate paths. People must make an effort to self-motivate and to continuously gain exposure to learning opportunities about new technologies, business models and ways to apply to new business contexts. People must leave their comfort zone and take risks to experiment the use and deployment of new solutions.

Individuals must be eager and open to new experiences and external stimuli, regardless of their age, academic background, professional experience or technology proficiency. Simultaneously, from school to companies, there must be a concern to create T-Wave learning environments, encouraging people's contact with technological developments. There is a need for private and public cooperation to promote stimuli contexts for individuals, while providing innovative ways to support the development of people's capacities and competences.

Finally, the existence and showcasing of role models that provide an example of how to learn to surf the T-Wave may open new horizons for individuals, leading to more entrepreneurial environments. This method has been present in the accelerators' recent activity which have brought T-Leadership role models to encourage other entrepreneurs to move their ideas forward and believe in their path.

Mentoring

Talents need guidance in order to cope with an evolving technological, social and economic environment. Mentoring is thus fundamental to exploit the individuals' potential and its absence may lead astray talents. Mentoring is not about telling people what to do, but rather to provide new insights and help individuals steer their talent development. Mentoring must be customized to each talent and adapted to the specificities of the environment.

An important dimension of mentoring is contributing to the talents' soft competences and skills. Although we are facing a second wave of technological impact, the drive for change is human-centred and thus, social skills like collaboration, negotiation, pitching, motivation, are more important than ever. But also relevant are traits like resilience, flexibility, self-confidence and will power.

Individuals must also seek ways to find adequate mentoring that transmit real and practical examples. A major way to enroll in practical mentoring is to engage in events or activities with experienced people, and learn by sharing real stories with each other. People in networks of existing businesses are a rich source of mentoring for the new and innovative entrepreneurs. But also incumbent technical people and managers have a lot to learn from new technical savvy people with no business experience. Moreover, a major strength in a successful mentoring process is the ability to promote exchanges between people from different domains, from arts to engineering, from healthcare to maths, etc.

Companies, universities, research laboratories, public governmental bodies, conferences, etc. are sources to find people that can provide relevant mentoring. Engaging in programs like technology bootcamps, accelerators, or other events prone to share experiences is also extremely relevant. Entrepreneurship programs like the Lisbon Challenge **[45]**, which thrive on promoting diversity and a multicultural environment by bringing together startups, people and formal mentors from all over the world are excellent examples of successful mentoring dynamics. The success of this type of event demonstrates the importance of improving and promoting private-public cooperation in effectively leveraging the specific competences and resources of each party.

A more recent trend is corporate acceleration programs where companies, operating in specific domains, look for problem solving solutions and provide mentors with market expertise and knowledge on the business domain at stake. Through these programmes, the companies put forward a call for entrepreneurs, typically, young talents who strive for new technological solutions in the areas of digital, genomics, materials or energy **[39]**. This combination of established incumbents with entrepreneurial startups environments, and the exchange between traditional technology and new unproven solutions, poses an innovative but interesting challenge.

Opportunities

With the T-Wave affecting society and economy, and rising pressure on employment and jobs, people must embrace opportunities to further develop their talents. There is often a misconception that, if people are not technological savvy on digital, genomics, materials or energy, they might be excluded from the opportunities offered by technology. Opportunities arise with problems people face everyday and everywhere, and are, especially more obvious to those who are able to combine knowledge and experience in specific business domains with the potential brought by technology. There is a massive window of opportunity to those that are willing to combine traditional businesses (restaurants, accommodation, transports, agriculture, etc.) with new technologies and business models. However, people must relentlessly seek their window of opportunity by continuously searching for pathways to fulfil their talents. Opportunity is about looking at the future regardless of one's performance in the past. It is about self-motivation and the willingness to excel, learning how to turn past failure into future success. Failure should be rather a part of a learning process in talent development. People likely to take the advantage of the T-Wave are those who believe that they can do better in the future because they have learned from past mistakes, and can embed the lessons learned in new endeavours.

Business and corporations must also nurture opportunities for their managers and workforce, as well as for society in general. The rising importance of the creative class in the context of the T-Wave must be recognized and valued by companies who should be providing "space and time" for individuals to develop their talents. This implies developing a corporate and organizational's culture which promotes and values people's talents and creativity, while boosting employees' motivation.

It further means that companies must radically change their recruitment approaches and appraisal mechanisms. Rather than only highlighting and rewarding past performance, talent management should look at the future, and establish criteria based on people's aspirations, their talent development potential, and willingness to evolve and learn within the organization.

Corporate Contests, Hackatons and Acceleration programmes

In the last five years a wide diversity of corporations in Portugal have embraced mechanisms to engage people, academics, researchers, startups, young and old entrepreneurs. These mechanisms may have different configurations, from challenges, contests, hackatons, acceleration programs, etc. Contrary to more general competitions, corporations tend to develop vertically-based mechanisms, strictly focused on their business areas. EDP´s Prémio de Inovação focuses on energy-related challenges; Valorsul's Prémio de Inovação addresses problems and challenges related with recycling; Siemens's Prémio Nova Geração is a contest for innovative ideas in engineering, and Hovione Capital offers initiatives in the field of life sciences.

More recently, a new trend emerged, in corporations, of developing vertical acceleration programs to look for solutions to problems faced by companies operating in specific fields. Deloitte Digital Disruptors' acceleration program focuses on digitalisation, whereas Fidelidade's Protechting acceleration program focuses on the quality of life and protection of people.

Most of these initiatives have two main goals. First, develop innovative ideas, in an open environment that can be fully exploited by the companies' new products development team, if these ideas prove to get traction and become successful. Second, stimulate and detect talents that had not been identified. These programs offer experienced mentoring, focused on assessing ideas and helping entrepreneurs and startups achieve success. Finally, provide the opportunity to the most promising talents to take their efforts further, by offering support, funding and engagement.

4. Learning T-Surf

This chapter describes how society and economy must adapt to grasp the opportunities and create new clusters for economic growth.

4.1 EDUCATING THE EDUCATORS

Universities are some of the oldest and resilient institutions of human civilization. The university institution has nearly 900 years and, despite its weaknesses, continues to shape human knowledge and is a paramount player in innovation ecosystems. The T-Wave has triggered some strong discussions in recent years, about the role of universities and other players in education.

The education problem is even more acute in Portugal, given our society and economy specific challenges. Portugal ranks in bottom EU and OECD positions on indicators related to the percentage of population with secondary and tertiary education and drop out ratios in all education levels. Moreover, we have currently one of the largest percentages of youth unemployment in the EU, many of them holding university degrees.

The discussion on the impact of the T-Wave in universities and their role in education is often excessively centred on the replacement of traditional classrooms with online learning. This, in reality, is a misplaced discussion. The question should rather be: How can universities and educators facilitate and enable change? We envision the following five main challenges:

T-Leadership in a time of specialisation

The T-Wave is pushing people to specialize in increasingly smaller and specific areas of knowledge, thus giving rise to higher levels of technological specialization. According to Empirica and IDC projections of economic activity and labour market trends, the demand for these skills will be greatest in roles that involve management and business analysis, for people with a technology leaders' profile **[46]**. Hence, this people must understand well the technology spectrum, but have the management competences and soft skills to address transformation in businesses. Successful companies and businesses, incumbents or startups, will be transformed by technology leaders, either in full-time or part-time capacities in their organizations. This will inevitably add more pressure to an already fraught situation, where the demand for technological (and particularly digital) skills – leadership and others – far exceeds supply. Hence, training and educational institutions need to produce people with the right technological leadership skills and entrepreneurial mindsets.

Thus, technological and digital leadership skills content must be included in all management training and educational programmes for business leaders and senior public officials. Strategies must be conceived to ensure that requirements for higher and continuous professional development institutions are being met.

T-Proficiency

There is a growing need for new, highly specialized skills, such as Big Data analysts, cyber-security specialists, cloud computing programmers, biomedical and Genomics experts, nano-materials engineers, aeronautical engineers, and designers of energy devices. Estimates in Europe and the US forecast a steady rise in engineering and science-based employment. In most EU countries, the number of new graduates in these areas is outpaced by job vacancies, particularly in the area of digital, cognitive computing and robots. There is a need to design measures and training programmes to fill the skills' gap in these increasingly important digital professions. Moreover, the increasing levels of specialization in all areas of knowledge and scientific domains must lead to academic programmes with higher levels of modularity and in-depth knowledge bases. In addition, these programmes must be integrated in flexible structures and include intelligent complementary syllabuses.

In parallel, it is of high importance that all traditional sectors and industries develop a coherent and efficient transition to an economy leveraged by the T-Wave. Education players, at all levels, must consider the new technologies in their training courses. Technology must naturally become embedded in the body of knowledge, rather than being an add-on to the subject matter. This should be particularly the case in the fields of digital, cognitive computing and robotics in elementary school syllabuses, which should be

Digital leadership programmes

The e-Leadership report of 2015, supported by the European Commission and issued by empirica GmbH, has acknowledged the EuroCIO Executive MBA in Corporate Information Management as the best practice in digital leadership education. The focus of the program is to link business and IT which is considered essential for successful corporate management **[46]**. The program consists of nine modules, with all business modules being lectured in the context of IT, while all technical or IT modules are lectured in the context of the business.

Moreover, the e-Leadership report of 2015 recognizes that only 21 programmes in Europe offer e-leadership programmes delivering the capability to lead experienced executives in business transformation.

incorporated in order to increase students proficiency and awareness of these scientific domains from early on.

Cross-fertilization of scientific domains

The pressure for higher levels of technological specialization, and the simultaneous demand for technological leadership profiles with management competences and soft skills, must not lead to an education system based on scientific domain silos. The creative-based economy requires greater cross-fertilization across specialized areas, blending disparate knowledge domains: engineering with Genomics, business with arts, materials with digital, etc. Education and training programmes should become more flexible and incorporate a combination of scientific domains that are traditionally set apart. The demand for cross-fertilization needs to be supported by increasing levels of course modularity in degree programmes. Universities and higher education institutions must implement effective ways to persuade students to combine knowledge areas that are traditionally offered in separate faculties or schools.

The emergence of the creative class will demand a new breed of academic environment, with cross-fertilization occurring not only in school curriculums, but also through greater social and academic exchanges between people from different knowledge and scientific backgrounds.
The relevance of this is well documented and, as a result, universities must develop formal and informal mechanisms to encourage students, professors, and researchers from different scientific domains and separate faculties to physically meet and exchange ideias.

Embedding practitioners in academia

Lecturing is often based on teachers/lectures with high levels of expertise on specific knowledge areas derived from their respective research work. Practitioners' experiences differ substantially from the world and realities of schools and academia. There is a need to design effective new forms of education and training programmes with higher levels of collaboration between academic faculty and staff, on the one hand, and experienced people from companies, public institutions and non-profit organizations, on the other. Over the last 10 years, large companies have established corporate academies for the training of their employees, but the focus has been very much on specific task training, falling short of meeting the challenges of the T-Wave.

The blend between the academic body of knowledge and practitioners empirical experience will reinforce the development of networks that act as triggers and nests for innovation and change. Students will benefit from real world learning experiences in the classroom and will have a clearer understanding on the obstacles and hinders that may come their way while developing solutions. Moreover, the problems they will face may become a relevant business source for driving new and innovative entrepreneurial activities.

Universities and training centres must also create new mentoring programs to develop talents in companies. These can complement traditional formal education programmes with more informal, but focused, mentorship, and avoid the burden of ~~a~~ participating in formal educational or training programs. These mentoring programs will offer flexibility on the topics addressed, and include a range of mentors from different scientific areas, and no formal syllabus to follow. This will also be different from traditional R&D consultancy services, as these tend to be focused on delivering a specific output, whereas the mentoring programmes would encourage openness and diversity.

The digital channel on a Professor's job

Much of the recent discussion about the impact of T-Wave in universities, and their role, has been related with the widespread emergence of Massive Open Online Courses (MOOCs) provided by entities like Coursera, Udacity, OpenClass e edX. These courses are taught by some of the most well-known professors and recognized universities.

The Watson University Program

Since its triumph on the television quiz show "Jeopardy!" in 2008, IBM has advanced Watson's capabilities and made it available via the cloud. Watson now powers new consumer and enterprise services in the healthcare, financial services, retail and education markets. IBM has also opened the Watson platform to developers and entrepreneurs, enabling them to build and bring to market their own, powered by Watson, applications for a variety of industries **[9]**.

The Watson University Program offers faculty members and students a range of opportunities for working with Watson's cognitive computing technologies, advancing student developer skills and fueling an ecosystem of innovators. Universities can get involved with Watson in several ways – from full semester courses to weekend hackathons. Also students and faculty can engage with cognitive services, gain valuable skills and broaden portfolios. IBM has created a network of partnerships with universities across the globe, in order to leverage the capacity of its cognitive computing platform through professors, researchers, students and entrepreneurs embedded in the academic environment.

The goal has been to provide access of higher education quality content to a wider public and democratize education. MOOCs have a potential to be a game changer in the education sector and disrupt education markets, since it changes both the delivery methods (digital) and the business models, as most MOOC courses are free, creating a potential revenue problem to universities. MOOCs are sometimes perceived as a potential threat to the conventional universities model, but many universities are still taking advantage of them to attract more students from all over the world. Actually, MOOCs can be a quite powerful marketing and sales channel for universities. Although different in its method, the Khan Academy with its online content, and teaching subjects from basic to high-school levels, may also introduce disruption in pre-university teaching, degrees and markets. Many other websites and mobile applications have been fast to address the education market. Overall, a plethora of MOOC resources, developed by private and public organizations, are today available, and mostly free. In addition, these MOOCs can easily be adapted and used by academia, enriching the content and dynamics of traditional education.

Despite the allure regarding the digital delivery of education, and its obvious tempting value proposition, this game changer apparently seems to be missing out on realizing its potential, with traditional teaching still holding, and teachers and educators seeming to be keeping their jobs. Recent numbers demonstrate that despite the fact that MOOCs have astonishingly reached around 25 million people from all over the world, only a very small fraction actually complete online courses (4%) **[48]**. Still, the overwhelming majority of people who complete MOOCs report having enjoyed career or educational benefits, while a substantial proportion mentioned tangible benefits, such as getting a new job, starting a business, or completing prerequisites for an academic program. Both career and educational benefits are more likely to be reported by people from developing countries, while tangible career benefits are more likely reported by people with lower levels of education and socioeconomic status. Among non-student attendees that complete the MOOCs, people with lower socioeconomic status, lower levels of education, and people from developing countries, are all more likely to report educational benefits. These results show evidence that MOOCs can provide a life-changing opportunity for those who are less advantaged and have limited access to education.

Being a better professor with the help of MOOCs

The challenge of captivating a vast, fickle audience as a way to reassess his own teaching techniques is in the heart of many professors that have engaged in MOOCs **[48]**. Producing video lectures spurs to hone pedagogical presentations to a far higher level than teaching the class on campus, if one wants to have impact. Online classes can, therefore, be significantly more rigorous and demanding than the on-campus version.

A key way professors are learning new teaching tricks is by taking cues from their MOOC students. Coursera, edX, and Udacity, all track the interactions students have with the course materials, and with one another, at a given course. Each platform then gives professors the ability to see data that could tell them, for example, which methods and materials help students learn and which ones they find extraneous or boring. The idea is to glean insights from the online courses that professors can apply in the traditional classroom, where such data is hard to come by.

The focus of change should be on how teachers may use their creative nature to deliver value to the students. This will imply new teaching methods, seeking to ignite talents in the classroom. Instead of replicating static knowledge on boards and asking students to respond to what has been said, teachers should be asking students what can be created with the knowledge and information they are given. The increasing importance of the creative economy must be accompanied by new teaching methods delivered by talented teachers, far more focused on fostering creativity, problem solving and divergent thinking, rather than narrow-thinking and imitation. The focus of the teacher activity shall be to contribute to liberate students' talents and broaden their professional horizons in the face of the T-Wave. The Web technologies should be used as an instrumental tool for extending knowledge access. Only in this way, teachers will create added value.

4.2 NURTURING TECHNOLOGY-BASED ECOSYSTEMS

Government, professional bodies and chambers of commerce must design ways to support the emergence of technology-based ecosystems and their players, however avoiding the temptation of deciding the future for them.

Technological transformation centres or clusters should be established in Portugal's main regions and cities for incumbent businesses and new startups to collaborate profitably and learn from each other. With visible political and industry sponsorship, the centres should bring leaders of businesses that can be transformed by embedding technology, together with successful leaders of new innovative, tech-rich businesses. These centres, which may take different forms, and build on what is already in place in different regional and local organizations, should focus on producing confident and competent T-Leaders, who become enthusiasts and able to technologically transform their businesses. Business leadership will be vital. Leaders need to be willing to become role models and talk about the challenges they overcame and the technological transformation journey they undertook.

This is expected to lead to successful collaborations between old and new businesses, providing large firms with access to an extended pool of knowledge, resources and ideas. Traditional firms see first-hand how innovative companies have used technologies, while smaller and newly created businesses have the opportunity to commercialize new ideas and expand their markets.

These technological transformation centres or clusters must be established as a network to develop best practices and provide intelligence that could be used to produce an evolving blueprint. The network should be supported by an online platform accessible to its members, and create connections among the plethora of initiatives, in Portugal (such as the COTEC initiatives) and across the EU, which deal with aspects of T-Wave transformation. It should also serve as a repository of lessons learned, and as a platform to combine the roles of the various players. These centres should assess the status of the local technological transformation, while engaging and providing the necessary mentoring to participants, from policy makers to businesses, sector representatives, social partners and third sector. Particularly relevant are actions to connect innovative technological startups with traditional companies, large companies with small innovative business, locally based companies with emergent global players.

These centres must develop local technological transformation action plans to stimulate research, innovation and entrepreneurship and create effective governance models to boost evolving ecosystems. Action plans must give practical guidance on how to encourage local business and entrepreneurs to take an active development role. Activities like challenges, competitions and reverse pitches – where traditional and innovative startups, social enterprises and businesses from different sectors are invited to provide technology based solutions to the most pressing urban challenges – should be promoted.

In recent years, there has been a few successful cases worth replicating to other technological domains, particularly in the health cluster and in internationally acclaimed digital ecosystems. In these fields, accelerators for pre-startups and startups encourage entrepreneurs to develop their technologies and market strategies at a faster pace, by engaging them in typically 2-3 month intensive programmes, where their business ideas are put to test and wide mentoring is supplied. These types of programmes focused on networking are excellent for testing and validating whether entrepreneurs can be successful, and accelerate success or failure, increasing productivity in the ecosystem. Also, in some situations, they act like venture capitalists taking equity in new innovative startups for their contribution to idea development and testing, and speeding up market access, thus serving as a mechanism for funding technological endeavors.

A Genomics-based ecosystem in Cantanhede

BIOCANT Park is the first Portuguese venue entirely devoted to biotechnology. Advanced Life Sciences knowledge and technology are developed and applied creating value in business initiatives **[49]**.

It was an audacious investment of the Municipality of Cantanhede and the Centre for Neuroscience and Cell Biology of Coimbra, which took advantage of recent Portuguese investment in Life Sciences. It was set out as a key part of an integrated strategy to promote entrepreneurship and economic growth.

The core of the Park is the R&D centre – BIOCANT, Biotechnology Innovation Centre – where specialized research teams use their built-up scientific competences to generate novel services and products. The scientific units of BIOCANT have committed staff and state-of-the-art equipment with high-throughput capacity.

Embedded in the local ecosystem is Biocant Ventures, the first Portuguese company whose main objective is to invest in biotech projects available to big investors. The goal is to test and validate early-stage concept and business ideas of biotechnology projects, as some of them cannot be legally supported by Venture Capitalists because are not yet formally registered as companies.

4.3 NO ONE'S LEFT BEHIND

Portugal has had some significant economic competitiveness and employment challenges resulting from the combination of the entry in the Eurozone, globalization and the financial crisis of 2008-2010. Long-term unemployment is still historically very high and is expected to last mainly among the unskilled and less qualified workforce. There is also a high youth unemployment rate, with a significant percentage holding tertiary degrees, though unemployment is less likely to last as long among this segment of the population. The T-Wave is expected to create further unemployment among rather skilled and qualified workers, as some of the traditional human-based cognitive tasks – in areas like transportation, services, medicine and others – will be replaced by digital applications and depend less on human intervention.

Recent studies have been highlighting the possible impact of game changing technologies on jobs and employment. Predictions reveal that most workers in transportation and logistics occupations, together with the bulk of office and administrative support workers, and labour in production occupations, are at risk **[75]**. A substantial share of employment in service occupations, where most job growth has occurred over the past decades, is highly susceptible to digitalization, supported by the recent growth in the market for service robots and the gradually diminishment of the comparative advantage of human labour's comparative advantage in tasks involving mobility and dexterity. The T-Wave will force low-skill workers to relocate to tasks that are non-susceptible to digitalization, and that require creative and social intelligence competences. For workers to win the race, however, they will have to acquire creative and social skills.

This is further supported by the recent World Economic Forum report *The Future of Jobs. Employment, Skills and*

Workforce Strategy for the Fourth Industrial Revolution that analysed the potential impact on 15 economies accounting for about 1.86 billion workers, approximately 65% of the world's total workforce for 2015-2020 **[76]**. Though the study predicts a grim unemployment problem, particularly for Office and Administrative job family, there are clearly very large growth opportunities for jobs in the Computer and Mathematical job family, centred on data analysts, software and applications. These opportunities will emerge not just within the Information and Communication Technology industry, but across a wide range of industries, including Financial Services & Investors, Media, Entertainment and Information, Mobility and Professional Services, as digitalization and robotics constitute a significant driver of employment growth **[60]**. Similar conclusions have been reached regarding the Australian economy **[77]**.

Hence, the creative class is likely to prosper in the coming years, as a result of the creative destruction movement caused by the T-Wave. But our society and public policies must provide support to the manufacturing and service classes who will be displaced by the Technological Wave. The answer may be related with fostering people's talent on a new economic context. This can be done by a combination of things, like helping people develop new skills and competences, fostering an entrepreneurial mind-set, and improving private-public cooperation. A good example is Activate, Google's training program that started in Spain, and that is now scaling to other European countries, which provides free training for students in digital skills such as digital marketing, cloud computing and e-commerce.

Entrepreneurial attitude is part of one's genes, but is also contingent on the education, social environment and economic context. Entrepreneurial attitude is not just about creating new business or startups, rather it is about how people addressing problems, challenges, barriers and setbacks within organizations, or in the process of developing new enterprises. Intrapreneurship is about an employee's act to take initiatives within the organization, without being asked to do so. This concept is becoming widely recognized in corporations as a major competence that employees must have, in order to succeed in an evolving and disruptive technological context. Capturing the dynamic nature of entrepreneurial thinking, like trying new things to succeed, learning from failures, attempting to do things with lean resources, etc., adds to the potential of an otherwise static organization, without exposing employees to the risks associated with entrepreneurial failure. Moreover, intrapreneurs should demonstrate courage and flexibility to think outside-the-box, and work on ideas that may change strategic direction. All this becomes critical in times of great technological change, where corporations must be swift to adapt to the external environment, hence making the intrapreneur's role in organizations more relevant than ever.

Society and governments cannot leave behind people potentially displaced by the T-Wave, but public finances will not be able to sustain a new wave of welfare consumerism. We need to proactively anticipate the social and economic challenges by designing new support mechanisms to release people's talents and entrepreneurial attitudes. The strategy should focus on preparing people to cultivate their talents in active working environments, while incorporating them in existing organizations or startups, rather than let people become unemployed and cut from economic activity. The focus should be on the skills and competences that are necessary to cope with today's new working and business realities. We need to strengthen the creative class with experienced people that develop their technological proficiency and leadership skills, whether they become intrapreneurs or entrepreneurs in their career development. There are likely many skilled people, within the services and manufacturing companies, whose talents should not go to waste or unnoticed, but rather leveraged differently.

Although the T-Wave will require T-Proficiency in disparate areas like robotics, renewable energy and storage, genomics or new materials, the greater skill gap pressure will unarguably occur in the digital and cognitive computing domains. Overall, every citizen will have to know basic digital skills in order to live, work, learn and participate in modern society. This reality will lead to an increasingly greater need for digital skills in nearly every job, where digital and cognitive computing complement existing traditional tasks. In the near future 90% of jobs – in engineering, accountancy, nursing, medicine, art, architecture, and many more – will require some level of digital skills. A huge gap will exist among more skilled digital savvy professionals in all sectors of the economy. It is estimated that there will be around 825,000 unfilled vacancies for digital-related professionals by 2020 **[46]**.

Governments and society must reinforce inclusive initiatives, aimed at increasing workforce digital skills training, dedicated to raising their potential to adapt to the new reality's requirements. In addition, those professional profiles, facing the risk of becoming a surplus in the job market, must be technologically converted to fill the vacancies in digital-related professions. The European Commission and national governments have acknowledged this challenge and adopted the European Digital Agenda and each country, within which, has adopted its own national Digital Agenda. In Portugal, the strategy needs to go further, regarding modernising training on digital technologies across the country. We need to be making effective and strong partnerships between local employment and training agencies, bringing together universities, private companies, municipalities and other players to harness digital learning, ensure skill validation and recognition, and anticipate digital skills needs.

A greater focus should be given to the currently skilled active workforce, which is likely to be affected by the T-Wave, by anticipating a significant problem, converting their profiles to the creative class and working to improve their digital savviness. Digital training co-designed with the industry should be offered, in a collaborative effort, to provide more digitally aligned degrees and *curricula*, at all levels, types of training and education. But it is also fundamental to motivate people to study digital domains and adapt their current careers to pursue new creative areas sustained by digital knowledge, creating greater value for their talents.

4.4 URGING QUICK POLICY ADAPTATION

Each sectorial area of government (education, health, justice, infrastructure, etc.) must be quick to respond to incoming changes and create a technology-friendly environment, while enabling and instigating proper legislation and societal initiatives. There are too many examples of innovative startups and business solutions that have emerged, in recent years, lacking sometimes the proper legal framework. There are well known public examples, like Uber or Airbnb, where incumbent businesses across the globe are trying to block their activity. Or the less known example of the "VAT MESS", where an unintended confusion emerged in digital markets over the changes in VAT rules introduced across the EU in January 2015.

The increasingly fast pace of change brought by the T-Wave will surely lead to many more of these situations where skill gaps will occur in all scientific domains, from digital, cognitive computing, robots, genomics and energy of materials. Not all areas will face the same relevance in terms of impact on skills and competences. Innovations and solutions related to human health will surely become more critical, especially if governments and legislators do not proactively anticipate and respond to innovation in the markets.

On the other hand, excessive restrictive national (and European) legislation will create disincentives and hamper the emergence of entrepreneurial activities and innovation from existing business.

Upgrading Europe through new economy skills

The Portuguese startup ALPHAPPL embraced a big societal challenge by positioning itself as a group of professionals working to solve the European skills gap and to fight unemployment **[50]**. The startup's main goal is to develop T-Proficiency and digital talent for people with or without IT skills, employed or unemployed, serving as a meeting point between talents and companies that need people with "new economy skills" (e.g. digital skills). A major goal is to convert people from non-IT background to coders.

ALPHAPPL offers full-time, intensive, and current courses in software development and other IT skills. Potential applicants don't need prior programming experience, but must exhibit motivation, and the business and technological ability to complete the class. In addition, students accepted in the course will complete work for real projects, in order to create a portfolio and convey a real sense of urgency.

Uncertainty is not going away anytime soon, and inaction cannot be the default response. So how should governments and legislators adapt?

Tech-Friendly Cities must be levers for startups and not battlegrounds

Boston is emerging as an unlikely battleground for web-based businesses like Airbnb and Uber, with more regulations to prevent the startups from disrupting communities and more established industries. Prompted by the arrival of the mobile app Haystack, Boston recently banned services that allow people to offer their public parking spaces for sale. The City Council is also considering restrictions on ride-sharing services like Uber, Lyft and Sidecar and lodging websites like Airbnb, HomeAway and FlipKey, which allow users to book short-term stays in private residences. Similarly, Cambridge, home to Harvard and MIT, has been trying for years to restrict rideshares **[51]**.

From San Francisco to Lisbon, cities have been wrestling with the same questions and developing solutions ranging from outright bans to minimum safety requirements. The issue is about balancing public safety and governmental oversight with the services' growing popularity.
But technology companies point out that the push for regulation is ironic as many technology-heavy cities have built their reputations, in large part, on being on the leading edge.

In opposing trend, are the visionaries' legislators regarding self-driving autonomous cars. In 2013, no US state legislature had even contemplated self-driving cars. In 2015, four states have passed legislation (California, Nevada, Florida and Michigan), and several more are considering it.
Nevada's DMV has issued the world's first autonomous vehicle test plates to Google. Why is this important? These states are likely to be early adopters of the new technology, which will lead to new entrepreneurial activities, becoming home grounds for new technology-related economic growth.

Cities with strong university life are being pressured, as their college students and young professionals – usually the early adopters of technology – comprise a large part of their populations. Historical urban centres are the ones that tend to have outdated and oftentimes byzantine local codes. Cultural shifts are happening in cities, globally.
As society evolves people expect new services, with the landscape constantly shifting. Cities must be working fairly swiftly to address these issues.

It is fundamental that Portuguese central, regional and local governments and legislators continuously scan current and new legislation that puts unnecessary barriers to new business models emerging, linked to innovation and new technologies. Such scan and examination is necessary, to identify whether the policy or the regulation at stake indeed exists for good reasons or, alternatively, new solutions need be found to foster emerging and disruptive markets. The important factor is that Portugal becomes a leader in designing policies to cope with the T-Wave, in order to encourage national and international innovative established corporations and entrepreneurs to scale up their businesses in Portugal. Portugal must be seen as an entrepreneurial economy and society that nurtures innovation and embraces change, rather than as an obstacle to the inevitable technological change.

Another fundamental step will be to develop guidelines designed to "sense-check" potential T-Wave unrelated legislation at an early stage of the policy cycle, when new proposals are being developed. The Technology Test (T-Test) will give legislators a framework for assessing the extent to which a proposal has negative or positive impacts on technological transformation. This needs to be done while assessing the medium and long-term impacts, as well as the short-term ones. If the negatives outweigh the positives, the legislators should then decide whether to cancel or change the proposal.

Government and legislators must also create decentralized mechanisms to collect, register and analyse ideas as to where improvements or additions to the regulatory environment could positively aid the transformation. These mechanisms should draw together, experts, as well as T-Leaders from industry and academia, and gather input from all the relevant stakeholders. This scanning of proximity must address impact of horizontal technologies, like digital and cognitive computing, as well as highlight policy and regulation in specific sectors, like healthcare, education, or environment sectors. These decentralized and open mechanisms must embrace talents' suggestions on policy and regulations that could impact technological transformation. This will help identify the obstacles that businesses, sector associations and consumers are encountering with legislation, the complexity of the regulatory framework, and the diversity of existing national rules. Experts must continuously map the obstacles businesses are facing, and crowd-source potential solutions. Recommendations could be made to revise the current Portuguese legislative framework, or introduce new instruments by including the results and the related proposals.

If Portugal becomes an early adopter of legislation adapted to new technologies, it can also positively influence European legislation, rather than a late adopter and follower of rules designed by others. Portuguese authorities should regularly contribute to the European Commission's Regulatory Fitness and Performance programme (REFIT), a rolling programme designed to create a clear, stable and predictable regulatory framework that supports growth and jobs **[52]**. Under the REFIT, the Commission is screening all EU legislation on an ongoing and systematic basis to identify and correct burdens, inconsistencies and ineffective measures.

4.5 SUPERVISING REGULATORS: TRIGGER FOR INNOVATION AND ENTREPRENEURSHIP

Fast technology developments require flexible legislation and regulations, but regulators often fail in their supervision role. Recent events like the Volkswagen's car emissions scandal, raises questions about the ability of the supervising role to be solely dependent on institutional regulator bodies, not only at the European or US levels, but also at the national EU member-state level. There is a need to increase the mechanisms to cross-check the activity of public services and government activity based on hard data, increasing transparency and accountability. With the advent of digital technologies in the T-Wave, particularly Internet of Things, Big Data, Data Analytics, and Interoperability, there must be conditions to find new ways to crowd-source supervision of regulators activities.

In recent years, governments have been leveraging this capacity through Open Data initiatives. Open Data is data made available by government, businesses and individuals for anyone to access, use and share **[54]**. Open Data helps governments to make public services more efficient and offers citizens insights into how governments work, improving public trust and boosting political engagement. A relevant side effect is to drive innovation and economic growth by revealing opportunities for businesses and start-ups to build new services.

A global movement to make government "open by default" picked up steam in 2013, when the G8 leaders signed an Open Data Charter – promising to make public sector data openly available, without charge and in reusable formats. In 2014, the G20 largest industrial economies followed up, by pledging to advance Open Data as a weapon against corruption, and the UN recognized the need for a "Data Revolution" to achieve global development goals.

Open Data has a strong potential to facilitate substantial improvement of transparency and accountability regarding the impact of governmental legislation and regulations towards the T-Wave. Open Data is also the basis for evidence-based policy, providing government, legislators and institutions with the ability to base their policy decisions on empirical data – data that is open to public scrutiny and debate. As at the EU level, and across the United Nations, this movement keeps its growing momentum, it will be possible to monitor the effectiveness of public services and governmental policy and public decision-making.
Moreover, with an increasing trend to persuade corporations to share their non-sensitive property data, overall supervision of economic activity will increase. The publication of this data will unarguably raise the scrutiny of T-Wave ecosystems.

Despite having proved to be a front-runner in the use of online services by public bodies, Portugal does not hold a relevant place in Open Data initiatives, ranking 29th in the Open Data Barometer, belonging to the cluster of Emerging and Advancing countries (developed countries are typically in the High Capacity cluster) **[54]**. Portuguese central, regional and local government bodies must seriously engage in disclosing data related to their activities and crowd-source for transparency and accountability. This will allow public data to have a significant potential to be reused in new products and services, while simultaneously address societal challenges. More data openly available will help entrepreneurs discover new and innovative solutions. Recent initiatives like the iGeo portal of Portuguese urban and environmental Open Data, or Lisboa Aberta, from the Municipality of Lisbon with Open Data sets related to the city of Lisbon, are steps in the right evolution.

Portuguese government must leverage for Open Data innovation, which implies public-private partnership programmes, challenge funds, roundtables, hackathons and innovation incubators. These initiatives must become business-as-usual for governments, creating spaces for collaboration around datasets and stimulating data reuse.
As evidence suggests, Open Data hackathons or incubators do not automatically result in scalable products or services, but they can provide a space for reimagining how government services could be delivered. There must be a capacity to absorb the innovative ideas that are prototyped with Open Data, and to create an enabling environment where social and economic innovations can scale.

Open Data ecosystems: innovation economy into government

The US Presidential Innovation Fellows (PIF) program was established in the White House in 2012 to attract top innovators into government, capable of tackling issues at the convergence of technology, policy, and process.
The PIF program is administered as a partnership between the White House Office of Science and Technology Policy (OSTP), the White House Office of Management and Budget (OMB), and the General Services Administration (GSA). In 2013, the PIF program established a permanent home and program office within GSA **[84]**.

The Presidential Innovation Fellows (PIF) program brings the principles, values, and practices of the innovation economy into government, through people, by pairing talented diverse technologists and innovators with top civil-servants and change-makers working at the highest levels of the federal government, to tackle some US biggest challenges. These teams of government experts and private-sector doers take a user-centric approach to issues at the intersection of people, processes, products, and policy to achieve lasting impact **[84]**.

Fellows selected for this unique and highly-competitive opportunity serve for 12 months, during which they will collaborate with each other and federal agency partners on high-profile initiatives aimed at solving big governmental and societal challenges, and building the culture of entrepreneurship and innovation within government. The fellows work with innovators in government to lead Open Data initiatives to get government open, and host challenges and events to engage other entrepreneurs. These include the Open Data Challenges, Global Development Data Jam, and most recently, the Open Data TechCamp, which connect civil society organizations from around the world with new and emerging technology resources, and provides a forum for the PIFs to connect with entrepreneurs and government officials that share the passion of using Open Data for global development.

5. Bridging the Gap: Fostering a Societal Cooperative Contract

The technological wave cannot be "surfed" without cooperation among the various players within Portuguese society and economy. There is an urgent need for cooperative practices between agents, leveraging networks between incumbents, companies, startups, universities, governments, unions, chambers of commerce and professional bodies.

The challenge is mounting and if Portugal wants to take advantage of the forthcoming opportunities, it must start acting now. The alternative pathway is to later complain about how technology innovation affected the competitiveness of our economy and led to an impoverished society. There are examples in the past, in the Portuguese shoe and apparel sectors, where the opening of European and global markets boosted a cooperative environment that led to a successful transformation in the last 15 years. The tremendous dynamism of the Digital entrepreneurship scene in Lisbon, in the recent years, provides a great example of a sucessful cooperative environment.

We have discussed how the response to the challenging T-Wave must come from within peoples' talents. But they cannot do it on their own, they will need stimuli, mentoring and opportunities. Governments can play a leading role by leveraging mobilization through developing a creative networking environment, leading to the rise of a stronger Portuguese creative class. To successfully cope with the forthcoming T-Wave we anticipate the need for a societal public-private cooperative contract between the various players, to spark creative technology-based talents.
In order to deliver this societal contract, we advocate the following three main recommendations:

Recommendation 1: An Educational Contract for the T-Wave

Public policy must promote an educational system that, at the different levels, focuses on talent development for the creative class. This educational system must move away from traditional silo-based scientific domains and rather favor cross-fertilization across areas, combining scientific academic rigor with practitioners' experience and knowledge base, thus spurring innovation and entrepreneurship.

Policy for the Educational Contract must consider the following goals:

- Education efforts must focus on the development of creative class talents. Design of educational programmes and courses must result from a joint co-creation effort between academia, incumbent companies, startups, and other economy and society players.
- Universities should foster technology stimuli, mentoring and opportunities for people to fully realize their potential in the areas they are confortable with.
- Universities, incumbent companies and startups must work together to develop T-Leaders, through courses that offer proficiency in technology, but also soft competences in management and leadership.

- Education players must consider that digital proficiency must start at all levels, from early childhood to faculty, and feature in all scientific domains and education areas.
- Education, and training programmes and courses must consider the technology dimension as embedded in the domain area, and not as an external element to it.
- Education, and training programmes and courses should promote blended learning, where students benefit from academic staff with rigorous scientific knowledge, and practitioners real world experiences.
- Universities and educators must promote cross-fertilization of scientific areas in formal and informal education models.
- Universities and training centres must promote mentoring programs to develop talents within companies.
- Teachers' main role must shift from merely passing on acquired knowledge to igniting creativity, and an entrepreneurial mindset among students. In other words, teachers' expectations of students must change as well.
- The educational system must leverage digital platforms as a knowledge repository (MOOCs).
- The educational system must work jointly with companies to start developing digital proficiency among the non-digital working force, working to convert talents, thus anticipating job redundancy originated with the T-Wave.
- Develop training courses on digital proficiency skills for people in different working environments.
- Training courses should target the workforce in manufacturing and services as a priority group, converting these talents to the digital savvy creative class.
- Design intelligent courses focused on adapting skills and competences towards digitalisation. These programmes should be jointly designed by different players including unions, employers, companies, education institutions and mentors.

Recommendation 2: Establish a Network of Technology Role Models

Government must design policy for supporting the emergence of more numerous and larger technology-based ecosystems, replicating the successes of the moulds, shoe and apparel sectors, and more recently the health cluster, and the digital entrepreneurship ecosystem. A prime lever of this policy must be the development of a network of national, regional and local technology leaders that act as role models for the ecosystems.

Policy for establishing a network of technology role models must consider the following goals:

- Create a physical or virtual network of centres/clusters which champions the technological innovation and entrepreneurship ecosystems, at the national, regional and local levels, while leveraging existing programmes and initiatives (e.g. incubators, COTEC, etc.), and promoting greater contact between companies and centres.
- The national, regional and local nodes of the networks should be led by a Technology Czar (T-Czar), preferably coming from the private sector, who leads each node's dynamism.
- Central, regional and local governments must support T-Czars to organize periodic hackathons, acceleration programmes and other similar events, bringing together incumbent companies and new technology entrepreneurs, large and small companies, local traditional businesses, and international players.
- Create a digital platform to support the network of centres/clusters, where different parties find a cooperative open environment, which serves as an evolving repository of lessons learned and best practices to illustrate what can be achieved.
- Events and initiatives must engage international players and bring them on-board, merging national events with international initiatives. Close connections should be developed with EU initiatives and programmes related to the T-Wave, taking advantage of existing European-wide networks.
- Address a continuous process of data collection and analysis which monitors the performance of the network's nodes.
- National champions should define national strategies for boosting innovative clusters, with specific plans of action at the regional and local levels.
- Develop liaisons between universities and various innovative and entrepreneurship initiatives, in order to achieve a strategic alignment between the nodes of the network, regarding technology maturity and talent development.

Recommendation 3: Develop Technology-Friendly Policy and Regulations

Portugal must be seen as an entrepreneurial society and economy which nurtures innovation and embraces change. Portuguese central, regional and local government bodies and legislators must lead in designing legislation and regulation to cope with the T-Wave, providing incentives to national and international entrepreneurs to scale up their successful business in Portugal.

Policy for establishing a technology-friendly policy and regulations must consider the following goals:

- Create a central office for scanning current and proposed national, regional and local legislation and regulation to identify barriers to T-Wave businesses innovation and entrepreneurship.
- Develop guidelines designed to "sense-check" potential T-Wave unrelated legislation at an early stage of the policy cycle, when new proposals are being developed. The Technology Test (T-Test) should assess the extent to which a proposal has negative or positive impacts on technological transformation.
- Develop decentralized crowd-sourced scanning of regulatory environments, addressing the impact of horizontal technologies as well as policy and regulation in specific sectors. This process should be involving T-Czars and the nodes of the technological clusters/ecosystems network members.
- Continuously map the obstacles businesses are facing, and crowd-source potential solutions. Provide recommendations, on the basis of that assessment, to revise the Portuguese legislative framework or introduce new instruments.
- Design strategies to positively influence European legislation and act as an early designer, and adopter of pioneering legislation. Portuguese authorities should regularly contribute to the European Commission's Regulatory Fitness and Performance programme (REFIT).
- Policy must leverage for Open Data innovation to facilitate improved transparency and accountability regarding the impact of governmental legislation and regulations on the T-Wave, improving public trust and boosting political engagement.
- Create public-private partnership programmes, challenge funds, roundtables, hackathons and innovation incubators, that become routine government actions, creating spaces for collaboration around datasets and stimulating data reuse. These initiatives can provide platforms for reimagining how government services could be delivered, helping to drive innovation and economic growth and to identify opportunities for businesses and startups to build new services.

Garret McNamara made history by surfing one of the biggest waves ever ridden. He put the small fishing town of Nazaré on the world map, breaking headlines around the world.
We are now facing a new Technological Wave, which no one knows how to ride.
Just like the wild giant waves of Nazaré, the upcoming T-Wave is unpredictable, and yet impossible to fully grasp.
It is unfolding at an unprecedented speed and is likely to lead to a creative destruction on a scale never seen before.
Every day we see evidence of this Technological Wave coming. We can watch this extraordinary wave unfold before our eyes and do nothing about it. Or we can choose to learn how to tackle and anticipate this global movement.
While too much focus has been put on the massive challenges it presents to our global order and society, the T-Wave brings unparalleled opportunities for those who, just like McNamara, are prepared to face the wave when it comes. Change comes with people.
In all big disruptive movements, and historical turning points, there are incredible opportunities to be taken by those who are willing to take risks and evolve.
The greatest game changer of all are the people, not the technology, per se. Technology is a lever, but it is people who should be steering the change.

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TITLE

Game Changers: Surfing the wave of technology disruption

COORDINATION

Platform for Sustainable Growth (PCS)

STEERING COMMITTEE

Jorge Moreira da Silva (Chairman, PCS)
José Manuel Pinto Paixão (Steering Committee Coordinator)
Carlos Pimenta
Catarina Horta
Filipa Newton
Marta Mucznik

RESEARCHER | AUTHOR

António Grilo

DESIGN

Forma design | Margarida Oliveira, Veronique Pipa

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