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Policy brief

The challenges and opportunities of framing the EC 2020 'challenges' as 'mission-oriented' policies

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Introduction

In recent years there has been a call for a return to 'mission-oriented' policies as a way to address 'grand societal challenges' related to issues such as health, ageing, climate change and ecological sustainability, including the European Commission's 2020 challenges. The report that follows, 'Mission-oriented Innovation Policy: Challenges and Opportunities' sets out how governments can do this.

The report, supported by ISIGrowth funding, has had significant impacts in both the UK and European spheres. It is cited in the United Kingdom's new Industrial Strategy, published in November 2017 (Department of Business, Innovation and Enterprise, 2017) and the Institute of Innovation and Public Purpose (IIPP) was invited to host a new independent Commission to solve grand challenges in innovation and industrial strategy with a mission-oriented framework.[1] The IIPP has also created a new global network for organisations seeking to develop a mission-oriented approach to innovation, the Mission-oriented innovation Network (MOIN).[2]

In the European sphere, the author of the paper, Mariana Mazzucato, was invited to write an agenda-setting report to inform the next round of EU H2020 funding: 'Mission-Oriented Research & Innovation in the European Union', published in January 2018. As part of the preparations for the report, a series of meetings were held with European stakeholders between December 2017 and February 2018, including European think tanks, professional research organisations, representatives of High Level R&I Expert Groups and European Commission Directorate Generals. This report is also reproduced in full below as evidence of ISIGrowth's impact on the EC 2020 challenges.

'Mission-oriented Innovation Policy: Challenges and Opportunities' sets out how it is possible to address 'grand challenges' by identifying and articulating concrete problems that can galvanise changes in production, distribution, and consumption patterns across multiple sectors. The paper considers the differences between 'old' and 'new' mission-oriented projects and argues that the latter are in some cases harder to link to the development of a concrete technology but equally require long-term commitments to the development of technological solutions.

The report argues that to develop and embed mission-oriented policy, it is necessary to recognise that markets themselves are outcomes of the interactions between both public and private actors, as well as actors from the third sector and from civil society. The role of the state is then not just about correcting 'market failures' but also about creating and shaping markets with a view to steering growth in particular

[1] See https://www.ucl.ac.uk/bartlett/public-purpose/partnerships/ucl-commission-mission-oriented-innovation-and-industrial-strategy-moiis

[2] https://www.ucl.ac.uk/bartlett/public-purpose/partnerships/mission-oriented-innovation-network

directions as well as just expanding the rate of growth.

In turn, this means a new approach to assessing policy impact is required. A mission-oriented framework requires continuous and dynamic monitoring and evaluation throughout the innovation policy process, in contrast to the market failure framework of static 'before and after' cost-benefit analyses.

Another consequence of failing to understand the dynamic between public and private sectors in driving innovation is that risks and rewards are misaligned. If the public sector compensates for the lack of private venture capital money going to early-stage innovation, it should be able to benefit from the wins, just as private investors do. Public sector agencies will also require support to deliver their side of the public-private collaboration. A self-fulfilling prophecy has set in where the more the public sector is perceived as simply 'facilitating' the so called 'wealth creators' in the private sector, the less money is made available to develop the wealth creating potential of the public sector. This in turn has also made working in the public sector less attractive.

Changing the discourse around wealth creation is key to this process. Public and private can form visions of what is to be created together, and how to divide both the risks and the rewards of the value that results. But the process requires public agencies to embrace risk and uncertainty, build explorative capacity and foster institutional learning. It is not mistakes that are to be feared but that lack of learning from them.

The changes in mind-set, theoretical frameworks, institutional capacities and policies required are by no means trivial, but equally mission-oriented innovation policy is far from being a step into the unknown. As set out in the paper, there is substantial theory, evidence, case studies and experience accumulated over many decades of successful practice.

Mission-oriented innovation policies: Challenges and opportunities[3]

Mariana Mazzucato[4]

Introduction

Countries around the world are seeking economic growth that is smart (innovation-led), inclusive and sustainable. Such ambitious goals require *re*-thinking the role of government and public policy in the economy. In particular, they necessitate a new justification of government intervention that goes beyond the usual one of simply fixing market failures. Policy in this context is also about co-creating and co-shaping markets—creating different criteria through which to justify, nurture and evaluate public policies.

The ambition to achieve a particular type of economic growth (smart, inclusive, sustainable) is a direct admission that economic growth has not only a rate but also a *direction*.[5] In this context, industrial and innovation strategies can be key pillars to achieve transformational change—in particular, by identifying and articulating new *missions* that can galvanise production, distribution and consumption patterns across various sectors. Addressing such challenges – whether traveling to the moon, battling climate change or tackling modern care problems– requires investments by both private and public actors.

Reconceptualising the role of the public sector

Mission-oriented public investments are not about de-risking and levelling the playing field, but tilting the playing field in the direction of the desired goals. This includes making strategic decisions on the kind of cross-cutting technological changes that will affect opportunity creation across sectors (eg internet, battery storage), the type of finance that is needed, the types of innovative firms that will need extra support, the types of collaborations with other actors to pursue (in the third and private sectors), and the types of regulations and taxes that can reward behaviour that is desired (eg rewarding long-term investments and reinvestment of profits rather than hoarding).

While public funding has always been important in the early, capital-intensive high-risk areas that the private sector tends to shy away from, modern day missions can provide an even more fervent ground for an ambitious catalytic role for Government in *creating and shaping markets* which provide the basis for private investment.

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[3] Originally published as Mazzucato (2017) 'Mission-oriented Innovation Policy: Challenges and Opportunities', UCL Institute for Innovation and Public Purpose Working Paper, (2017-1)., available online at https://www.ucl.ac.uk/bartlett/public-purpose/publications/2018/jan/mission-oriented-innovation-policy-challenges-and-opportunities

[4] Institute for Innovation and Public Purpose, University College London

[5] The direction of innovation was emphasised by Richard Nelson in the 1960s through his NBER work on "The rate and direction of inventive activity" (see: http://www.nber.org/chapters/c2110.pdf), and more recently through the work of Andy Stirling in his work on pathways of innovation. See: Stirling, A. (2008) "'Opening up' and 'closing down' power, participation, and pluralism in the social appraisal of technology." *Science, Technology & Human Values* 33 (2): 262–294

From sectors to missions

Mission-oriented thinking requires understanding the difference between (1) industrial sectors, (2) broad challenges, and (3) concrete problems that different sectors can address to tackle a challenge. Sectors define the boundaries within which firms operate, such as transport, health or energy. A challenge is a broadly defined area which a nation may identify as a priority (whether through political leadership, or the outcome of a movement in civil society). These may include areas like inequality, climate change, or the challenges of an ageing population.

Missions, on the other hand, involve tackling specific problems, such as reducing carbon emissions by a given percentage over a specific year period. They require different sectors to come together in new ways: climate change cannot be fought by the energy sector alone. It will also require changes in transport and nutrition, as well as many other areas.

As industrial strategy makes a return globally, a mission-based approach can help to ensure that industrial policy does not end up as merely a static list of sectors to support. Rather, mission-oriented policies should focus on creating system-wide transformation across many different sectors.

For example, the Apollo mission to the moon required innovation across many different high-tech sectors (eg aerospace) and low-tech sectors (eg textiles). While the mission itself was top down in vision, it was the bottom-up experimentation around solving dozens of 'homework problems', involving different types of partnerships that galvanised the ensuing growth.

Similarly, the *Energiewende* policy in Germany today is a concrete mission with a specific target to reduce carbon emissions over a specific period of time, aimed at tackling a broadly defined challenge (fighting climate change). This has required many sectors, including traditional ones, to transform themselves. The German steel industry, for example, has lowered its material content through transformative policy that required repurpose reuse and recycling activities. While the man on the moon mission was decided top-down via political leadership, the German *Energiewende* policy was the result of bottom-up green movements, which culminated in political understanding and eventually leadership from above. Missions may require consensus building in civil society, combining the need to set directions from above with processes of bottom-up experimentation from below.

Missions around sustainability and green growth will similarly require many different sectors to rethink themselves, and to work together in dynamic and interconnected ways. Amongst other things, this can lead to more 'additionality' in business investment, helping companies in different sectors to make investments that would otherwise have not been made—extremely important in countries experiencing low business investment.

Risks, rewards and institutional capacity

Investments in industrial transformation, R&D, human capital formation and innovation take time. They involve high risks as there is no guarantee that the investment will pay off. But they are often worth both the wait and risk as they are the key source of productivity-enhancing innovation, creating well-paid jobs and a higher multiplier effect than other types of governmental expenditures.

Crucial to the implementation of a mission-oriented approach to innovation policy is the need to reinvigorate capacity building, competencies and expertise within the state (the 'developmental and networked' entrepreneurial state, as referred to below) such that its different organisations can effectively fulfil their roles in coordinating and providing direction to private actors when formulating and implementing policies that address societal challenges through innovation.

This scoping document outlines the challenges and opportunities of reviving industrial and innovation policies with a mission-oriented lens. This paper aims to spark new thinking around the following:

- the possibilities of using **mission-oriented strategies** directed at solving concrete societal and/or technological challenges;
- the importance of a **systemic approach** to industrial and innovation strategies, and the problems that can result when such an approach is lacking;
- the need to see industrial strategy as an **interaction between multiple actors i**n both public and private sectors;
- the need for decentralised, networked entrepreneurial public organisations to be positioned strategically along the **entire innovation curve** (eg not just upstream in science or downstream in procurement), including the ability to make bold *demand-side* policies that change consumption and investment behaviour;
- ways in which industrial strategy can be used **to direct a green growth agenda**;
- the role **public investment banks** can play in providing **patient long-term strategic finance** to high risk and capital intensive projects, crowding in future business investment.

Grand challenges and 'wicked problems'

The 21st century is becoming increasingly defined by the need to respond to major social, environmental and economic challenges. Sometimes referred to as 'grand challenges', these include environmental threats like climate change, demographic, health and wellbeing concerns, as well as the difficulties of generating sustainable and inclusive growth. These problems are 'wicked' in the sense that they are complex, systemic, interconnected and urgent, requiring insights from many perspectives. Poverty cannot be solved without attention to the interconnections between nutrition, health, infrastructure and education. Grand challenge thinking is being applied both in developed and developing countries, with some of the most interesting experiments around sustainability being driven by the needs of emerging economies.

Mission-oriented innovation and grand challenges

This type of broad-based innovation policy has been called 'mission-oriented' for its aim to achieve specific objectives.[6] [7] It does not facilitate innovation merely by levelling the playing field with horizontal policies that prescribe no direction. On the contrary, such policies, by definition, give

[6] Ergas, H. (1987) 'Does technology policy matter', Technology and global industry: Companies and nations in the world economy, pp. 191-245; Freeman, C. (1996) 'The Greening of technology and models of innovation', Technological Forecasting & Social Change, 53(1), pp. 27-39.

[7] Mazzucato, M. (2014) Think Piece: "A Mission Oriented Approach to Building the Entrepreneurial State", paper commissioned by Innovate UK-Technology Strategy Board November 2014T14/165. Available at: https://www.gov.uk/government/news/long-term-growth-innovations-role-in-economic-success.

explicit technological and sectoral directions to achieve the 'mission'. At the same time, to be successful, they must also enable bottom up experimentation and learning.[8]

Examples of such direction-setting policies abound, including different technology policy initiatives in the US,[9] France,[10] the UK,[11] and Germany.[12] These policies were implemented by mission-oriented agencies and policy programmes: military R&D programmes; the National Institutes of Health (NIH);[13] grand missions of agricultural innovation;[14] and energy.[15] In these examples, the organisation made choices on what to fund: opting to tilt the playing field rather than only 'level it'.[16] Thus the 'picking winner' problem, which continues to dominate the industrial policy debate, is a static one that creates a false dichotomy: what is crucial is not whether choices must be made, but how 'intelligent' the picking of 'directions' can be.

The fact that the United Nations has reached agreement across 17 sustainable development goals, encompassing 169 targets, is an opportunity for mission-oriented investments today.

While the literature has focused largely on mission-oriented policies in developed countries, there are perhaps more opportunities in developing countries due to the greater 'challenges' they face. Indeed, mission-oriented policies could be a way for the natural resource curse to be approached: rather than natural resources being seen as belonging to a particular sector, they could be viewed as part of a solution to a greater mission. What are the missions that innovations in precious metals can help address? What are the missions that innovations in biotechnology and agribusiness can address? How can a 'green growth' strategy help address innovations in traditional sectors that must lower their material content?

A second problem (besides ignoring developing countries) is that the literature on mission-oriented policies has not integrated empirical insights to provide a full-fledged theory able to replace the orthodox view of directionless policy. Consequently, studies have resulted in ad-hoc theoretical understandings and policy advice on how to manage mission-oriented initiatives, without tackling the key justifications for mission-oriented policies that contrast those of simply fixing market failures.

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[8] Rodrik, D. (2004) 'Industrial Policy for the Twenty-First Century', John F. Kennedy School of Government Working Paper Series, rwp04-047.

[9] Mowery, D. C., Nelson, R. R. and Martin, B. R. (2010) 'Technology policy and global warming: Why new policy models are needed (or why putting new wine in old bottles won't work)', Research Policy, 39(8), pp. 1011-1023.

[10] Foray, D., David, P. A. and Hall, B. (2009) 'Smart Specialisation. The concept', Knowledge Economists Policy Brief (Expert group on Knowledge for growth), (9).

[11] Mowery, D. C., Nelson, R. R. and Martin, B. R. (2010) "Technology Policy and Global Warming: Why New Policy Models are Needed (Or Why Putting New Wine in Old Bottles Won't Work)." Research Policy, 39: 1011–1023.

[12] Cantner, U. and Pyka, A. (2001) 'Classifying technology policy from an evolutionary perspective', Research Policy, 30(5), pp. 759-775.

[13] Sampat, B. N. (2012) 'Mission-oriented biomedical research at the NIH', Research Policy, 41(10), pp. 1729-1741.

[14] Wright, B. D. (2012) 'Grand missions of agricultural innovation', Research Policy, 41(10), pp. 1716-1728.

[15] Anadon, L. D. (2012) 'Missions-oriented RD&D institutions in energy: a comparative analysis of China, the United Kingdom, and the United States.' Research Policy 41(10), pp. 1742-1756.

[16] Mazzucato, M. and Perez, C. (2015) 'Innovation as growth policy', in Fagerberg, J., Laestadius, S. & Martin, B.R. (eds.) The Triple Challenge for Europe: Economic Development, Climate Change, and Governance. Oxford: OUP, pp. 229-264.

In a market failure framework, *ex-ante* analysis aims to estimate benefits and costs (including those associated with government failures), while *ex-post* analysis seeks to verify whether the estimates were correct and the market failure successfully addressed. In contrast, a mission-oriented framework requires continuous and dynamic monitoring and evaluation throughout the innovation policy process.

In its most general form, the mission-oriented framework differentiates between public policies that target the development of specific technologies in line with state-defined goals ('missions') and those that aim at the institutional development of a system of innovation.[17] The State must therefore be able to learn from past experiences in mission-oriented innovation policy.

Systemic mission-oriented policies must be based on a sound and clear diagnosis and prognosis (foresight). This requires not only the identification of missing links, failures and bottlenecks – the weaknesses or challenges of a national system of innovation – but also recognition of the system's strengths. Foresight is necessary in order to scrutinise future opportunities and identify how strengths may be used to overcome weaknesses. This diagnosis should be used to devise concrete strategies, novel institutions and new linkages in the innovation system.[18]

Mission-oriented policies can therefore be defined as systemic public policies that draw on frontier knowledge to attain specific goals, or "big science deployed to meet big problems".[19] The archetypical historical mission is NASA putting a man on the moon. Contemporary missions aim to address broader challenges that require long-term commitment to the development of many technological solutions.[20] The active role being taken by the public sector towards renewable energy investments can be seen as a new mission in relation to the green economy. Other new missions include addressing such 'grand societal challenges' as the ageing/demographic crisis, inequality and youth unemployment.[21] In fact, these challenges – which can be environmental, demographic, economic or social – have entered innovation policy agendas as key justifications for action, providing strategic direction for funding policies and innovation efforts.

However, modern missions are more complex because there are fewer clear technological challenges and outcomes are less clearly defined.[22] One could add that these challenges also require changes at the societal/national systems level. The so-called Maastricht Memorandum provides a detailed analysis of the differences between old and new mission-oriented projects (Table 1).

[17] Ergas, H. (1987) 'Does technology policy matter'; Cantner, U. and Pyka, A. (2001) 'Classifying technology policy from an evolutionary perspective'.
[18] Mazzucato M. (2016a) "From Market Fixing to Market-Creating: A new framework for innovation policy", Special Issue of Industry and Innovation: "Innovation Policy – can it make a difference?", 23(2).
[19] Ergas, H. (1987) 'Does technology policy matter'.
[20] Foray, D., Mowery, D. and Nelson, R.R. (2012) "Public R&D and Social Challenges: What Lessons from Mission R&D Programs?". *Research Policy,* 41: 1697–1702.
[21] European Commission (2011) Green Paper–From Challenges to Opportunities: Towards a Common Strategic Framework for EU Research and Innovation Funding. Brussels: European Commission.
[22] Foray, D., Mowery, D. and Nelson, R. R. (2012) "Public R&D and Social Challenges: What Lessons from Mission R&D Programs?".

Table 1: Characteristics of old and new mission-oriented projects[23]

)efense, nuclear and aerospace	New: Environmental technologies and societal challenges
Diffusion of the results outside of the core of participants is of minor importance or actively discouraged	Diffusion of the results is a central goal and is actively encouraged
The mission is defined in terms of the number of technical achievements, with little regard to their economic feasibility	The mission is defined in terms of economically feasible technical solutions to particular societal problems
The goals and the direction of technological development are defined in advance by a small group of experts	The direction of technical change is influenced by a wide range of actors including government, private firms and consumer groups
Centralised control within a government administration	Decentralised control with a large number of agents involved
Participation is limited to a small group of firms due to the emphasis on a small number of radical technologies	Emphasis on the development of both radical and incremental innovations in order to permit a large number of firms to participate
Self-contained projects with little need for complementary policies and scant attention paid to coherence	Complementary policies vital for success and close attention paid to coherence with other goals

Source: modified version of table 5 in Soete and Arundel (1993, p. 51).

Although the memorandum specifically focuses on mission-oriented programmes that tackle environmental challenges, its analysis applies to other contemporary challenges (water and food supply, energy efficiency and security, disease, demographic change, etc). This is because these challenges all present similar characteristics, particularly that new technological solutions to address them will require long-term commitment from both public and private agents. The diffusion of solutions to a broad base of users is key.

One of the most pressing contemporary challenges is the need for *inclusion* of vast numbers of people in the innovation process and the socio-economic system as a whole, in order to tackle the issue of inequality. A recent and flourishing body of literature has explored the connections between innovation and systems of innovation and social inclusion. Issues of social development are being studied and targeted in policy action under the heading of 'social innovation'. Some missions will address inequality directly, others indirectly. In some cases, complementary investment in infrastructure and skills will be required if innovation policies are to be effective in addressing inequality. A mission-oriented policy agenda would increase the effectiveness of innovation policy and also has the potential to help rebalance public finances, not by cutting expenditures – as in the prevailing austerity agenda (which often affects the most vulnerable parts of the population) – but by increasing strategic investments that, due to the higher multiplier effect, would increase future revenues.

The six characteristics of contemporary missions identified in Table 1 – diffusion of technologies, economic feasibility, shared sense of direction, decentralised control by public agencies,

[23] Soete, L. and Arundel, A. (1993) An Integrated Approach to European Innovation and Technology Diffusion Policy: A Maastricht Memorandum, Luxembourg: Commission of the European Communities, SPRINT Programme.

development of both radical and incremental innovations, and enabling complementary policies – are of pragmatic importance for the promotion and implementation of mission-oriented policies.

A mission-oriented approach highlights the need to make a precise diagnosis of the technological, sectoral, or national innovation system that an innovation policy wishes to transform. The alignment of different types of capabilities is key for the success of any mission-oriented policy. These can be described as:[24]

- **Missions should be well defined.** More granular definition of the technological challenge facilitates the establishment of intermediate goals and deliverables, and processes of monitoring and accountability. When governance is too broad, it can become faulty, and there is a risk of being captured by vested interests.
- **A mission does not comprise a single R&D or innovation project, but a portfolio of such projects.** Because R&D and innovation is highly uncertain, some projects will fail and others will succeed. All concerned should be able to accept failures and to use them as learning experiences. Furthermore, stakeholders should not be punished because of failures derived from good-faith efforts.
- **Missions should result in a trickle-down effect**, whereby the priorities are translated into concrete policy instruments and actions to be carried out by all levels of the public institutions involved. While these missions should involve a range of public institutions, it is crucial that there is a strategic division of labour amongst them, with well-defined responsibilities for coordination and monitoring.

These considerations point to the need to adopt a pragmatic approach to defining missions. Chosen missions should be feasible, draw on existing public and private resources, be amenable to existing policy instruments, and command broad and continuous political support. Missions should create a long-term public agenda for innovation policies, address a societal demand or need, and draw on the high potential of the country's science and technology system to develop innovations.

From directed policy to bottom-up experimentation across sectors

"The design of a good policy is, to a considerable extent, the design of an organisational structure capable of learning and of adjusting behavior in response to what is learned" **Richard Nelson and Sydney Winter**, 1982[25]

"[S]hift from total confidence in the existence of a fundamental solution for social and economic problems to a more questioning, pragmatic attitude –from ideological certainty to more open-ended, eclectic, skeptical inquiry" **Albert Hirschman**, 1987[26]

To a certain extent, providing a straightforward list of missions for a country contradicts the core element in successful mission-oriented programmes. Missions should be determined through a fine-tuned diagnosis of the problem and solution that involves stakeholders, draws on the strengths of the country's system of innovation and considers ways to overcome its weaknesses. Who decides

[24] Mazzucato, M. and Penna, C. (2016a) 'The Brazilian Innovation System: A Mission-Oriented Policy Proposal', Report for the Brazilian Government commissioned by the Brazilian Ministry for Science, Technology and Innovation through the Centre for Strategic Management and Studies, (06/04/2016). Available at: https://www.cgee.org.br/the-brazilian-innovation-system.

[25] Nelson, R. R. and Winter, S. G. (1982) An Evolutionary Theory of Economic Change. Cambridge (MA): Belknap Press.

[26] Hirschman, A. O. (1987) The political economy of Latin American development: seven exercises in retrospection, Latin American Research Review, vol. 22, No. 3, Washington, D.C.

the mission is a key issue that requires more thought. While the moon-shot mission was to a large extent a top-down mission led by President Kennedy, the effects of the process—many of which are in our 'smart' products today—occurred through the bottom-up interaction between different types of organisations that each took a part of the challenge. The modern day obsession with commercialisation strategies ironically has led to less commercialisation results than those policies that focused less on the result and more on the process. In this sense, mission-oriented thinking can learn from Hirschman's emphasis on 'policy as process' and the need to welcome serendipity and uncertainty – what he called the 'hiding hand'.[27]

The nature of bottom-up experimentation is key. Industrial strategy requires both horizontal and vertical policies working together systemically. Traditionally, industrial strategy often focuses on (vertical) sectoral interventions. Until the end of the 1970s this consisted of various measures ranging from indicative planning to outright nationalisation of entire industries (eg steel, coal, shipbuilding, aerospace and so on).

Although certain sectors might be more suited for sector-specific strategies, there are good reasons for avoiding a sectoral approach – particularly when private lobbying interests may prevail in negotiating specific provisions with the government,[28] negatively influencing the industrial strategy with indirect measures (eg tax credits) that potentially waste public funds and create little if no additionality in terms of new investment. The patent box tax incentive represents an example of these misconceived policies since there is no reason to lower tax on monopoly profits and it provides little incentive for additional research investment.[29] In countries where business investment in R&D (BERD) continues to be below the OECD average, sectoral policies risk allowing the private sector to continue to ask for subsidies or support, rather than fundamentally transforming themselves.

The case for building a modern industrial strategy on the identification of challenges, rather than sectors, is compelling and increasingly recognised. A mission-oriented approach uses specific challenges to stimulate innovation across sectors. Through well-defined missions – focused on solving important societal challenges related to climate change and environmental quality, demographic changes, health and wellbeing, mobility issues etc – the government has the opportunity to determine the direction of growth by making strategic investments throughout the innovation chain and creating the potential for greater spill-overs across multiple sectors, including low-tech sectors.[30]

Germany's *Energiewende* is a model of how to implement an integrated strategy that addresses several sectors and technologies in the economy and enables bottom-up learning processes. With its missions to fight climate change, phase-out nuclear power, improve energy security by substituting imported fossil fuel with renewable sources, and increase energy efficiency, *Energiewende* is providing a direction to technical change and growth across different sectors through targeted transformations in production, distribution and consumption.

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[27] Hirschman, A. O. (1967) 'Development Projects Observed'. Brookings Institution Press.

[28] Buchanan, J. M. (2003) "Public Choice: The Origins and Development of a Research Program". *Champions of Freedom*, vol. 31, pp. 13-22.

[29] Griffith, R., Miller, H. and O'Connel, M. (2010) "Corporate Taxes and Intellectual Property: Simulating the Effect of Patent Boxes". IFS Briefing Note 112, Institute for Fiscal Studies.

[30] Foray, D., Mowery, D. D. and Nelson, R. R. (2012) "Public R&D and Social Challenges: What Lessons from Mission R&D Programs?".

This has allowed even a traditional sector like steel to use the 'green' direction to renew itself. Indeed, German innovation policy has placed pressure on steel to lower its material content through the use of a 'reuse, recycle, and repurpose' strategy.[31]

Making markets – not only fixing them

The idea that the State is at best a fixer of markets has its roots in neoclassical economic theory, which asserts that competitive markets will bring about optimal outcomes if left to their own devices. This theory justifies government 'intervention' in the economy only if there are explicit *market failures*, which might arise from the presence of positive externalities (eg public goods like basic research, which require public sector spending on science), negative externalities (eg pollution, which require public sector taxation) and incomplete information (where the public sector may provide incubators or loan guarantees).[32] On top of this, the literature on systems of innovation has also highlighted the presence of system failures—for example the lack of linkages between science and industry—requiring the creation of new institutions enabling those linkages.[33]

And yet the recent history of capitalism depicts a different story – one in which different types of public actors have been responsible for actively shaping and creating markets and systems, not just fixing them; and for creating wealth, not just redistributing it. Indeed, markets themselves are outcomes of the interactions between both public and private actors, as well as actors from the third sector and from civil society. Mission-oriented innovation policy in this context is about the creation of new markets, not fixing existing ones—and yet this framework has not yet debunked the market fixing policy framework. Indeed, even the systems of innovation literature has not fully divorced itself from a 'fixing' perspective, as the way it is often interpreted is in terms of fixing system failures (eg formulating the missing links between science and industry).[34]

Systems of innovation

"The elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge … and are either located within or rooted inside the borders of a nation state"

Bengt-Ake Lundvall, 1992[35]

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[31] BMUB (2016) "German Resource Efficiency Programme II". Available at: http://www.bmub.bund.de/fileadmin/Daten_BMU/Pools/Broschueren/german_resource_efficiency_programme_ii_bf.pdf.

[32] Reviews of the impact of positive externalities and incomplete information on innovation financing is provided in Hall (2002), Hall and Lerner (2009) and more recent evidence is reviewed in Kerr and Nanda (2014). The role for government in the face of negative externalities (climate change) is laid out in Jaffe *et al.* (2005).

[33] Lundvall, B.-A. (1992) 'Introduction', in Lundvall, B.-A. (ed.) National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. London: Pinter, pp. 1-20.

[34] *Ibid*.

[35] *Ibid*.

Innovation policy is not just about funding R&D but creating systems which allow new knowledge to diffuse across an economy and create transformative change, including increases in productivity.[36] A *narrow* perspective on systems of innovation can be differentiated from a *broad* perspective.[37] The *narrow* perspective is focused on the science and technology subsystem (which includes capacity-building, training and formal education, plus science- and technology-related services) and its relationship with the production and innovation subsystem (where firms mainly operate). The *broad* perspective includes other subsystems and contexts: for example the subsystems of policy, promotion, representation and financing; demand (market segments); and the (geo)political and socio-economic context.

Figure 1 depicts a generic national system of innovation. Each level sustains and influences the other. Although the depiction implies a linear hierarchical relationship, in reality, there are mutual causations and flat hierarchies. Thus, there is no unidirectional causality, for example, from policies or science to market strategies and innovation. Nor is there an implication that any layer or subsystem is more important than others.

At the base of a national innovation system is the socio-economic, political, cultural, and environmental context. The next layer up is the government and state apparatus, which is responsible for public policy-making and funding. This is the subsystem of public policies/regulations and funding. Two other subsystems are the subsystem of production and innovation, which is populated mainly by business firms and their R&D labs, and the subsystem of research and education, which includes research and technology institutions (including universities and public R&D labs, but also other education organisations).

These two subsystems operate on a broad knowledge base, and may collaborate with each other. Firms in the innovation and production subsystem engage in market exchanges selling/buying goods and services to/from consumers/suppliers. Universities and research institutes engage in market exchanges for knowledge and human resources. Both of these subsystems may also draw on financial markets for funding and investments.

Nature of actors and interactions

Systems and eco-systems of innovation (sectoral, regional and national) require the presence of dynamic links between the different *actors* and institutions (firms, financial institutions, research/education, public sector funds, intermediary institutions) as well as horizontal links *within* organisations and institutions.[38] What, also should be emphasised, and has not been thus far in the

[36] Freeman, C. (1987) Technology Policy and Economic Performance: Lessons from Japan. London: Pinter.; Lundvall, B.-A. (1992) 'Introduction', in Lundvall, B.-A. (ed.) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter, pp. 1-20.

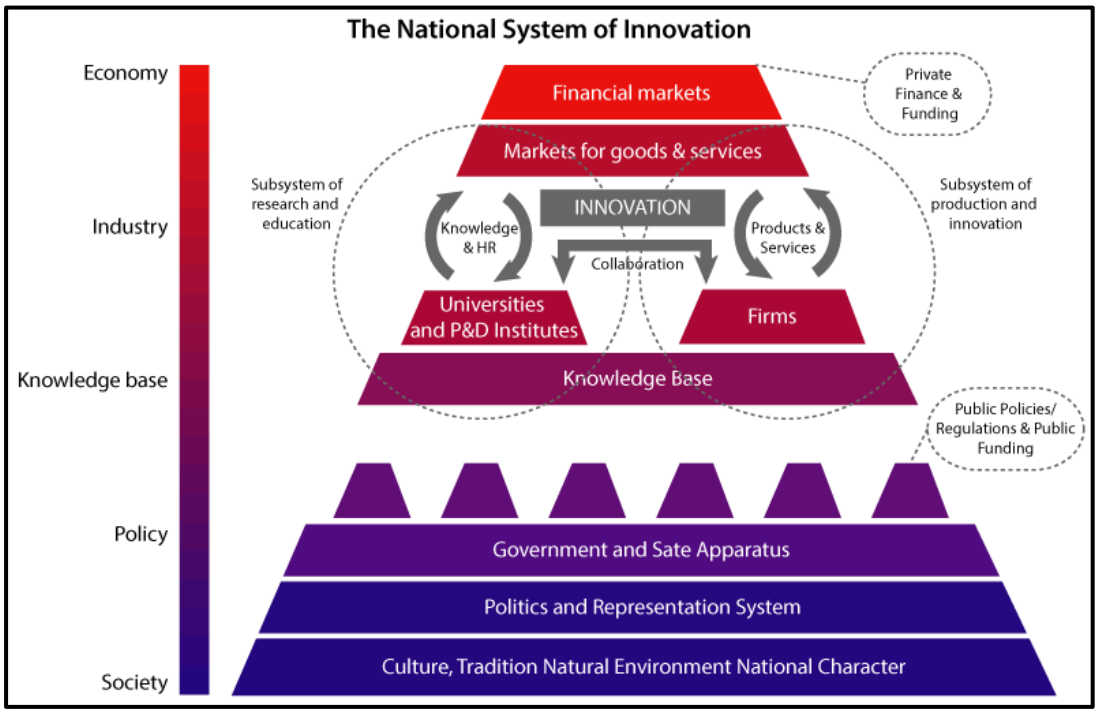
[37] Cassiolato, J. E. (2015) 'Evolution and Dynamics of the Brazilian National System of Innovation', in Shome, P. & Sharma, P. (eds.) Emerging Economies: Springer India, pp. 265-310.

[38] Freeman, C. (1995) 'The 'National System of Innovation' in historical perspective', Cambridge Journal of economics, 19(1), pp. 5-24.

literature on systems of innovation, is the nature of the actual actors and institutions required for innovation-led growth.[39]

In order to stimulate the innovation process by shaping and creating technologies, sectors and markets, dynamic relationships must be developed which create trust between actors. It is essential in this process for the lead public organisations to galvanise the interests of relevant actors and organise itself so that it has the 'intelligence' to think big and formulate bold policies that create a sense of ownership amongst diverse public, private and academic stakeholders. It is also crucial to be able to implement the policies by coordinating the efforts of this network of stakeholders through the state's convening power, brokering of trust relationships, and the use of targeted policy instruments.

Figure 1: Representation of a national system of innovation



Source: figure created by Mazzucato and Penna (2016) based on diagram prepared by the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT, 2002).

Because innovation is extremely uncertain, the ability to experiment and explore is key for a successful entrepreneurial state.[40] Therefore, a crucial element in organising the state for its entrepreneurial role is *absorptive capacity* or *institutional learning*.[41] Governmental agencies learn in a process of investment, discovery, and experimentation that is part of mission-oriented initiatives.

[39] Mazzucato M. (2016a) "From Market Fixing to Market-Creating: A new framework for innovation policy".
[40] Hirschman, A. O. (1967) 'Development Projects Observed'; Rodrik, D. (2004) 'Industrial Policy for the Twenty-First Century'; Mazzucato, M. (2013) The Entrepreneurial State: Debunking the Public Vs. Private Myth in Risk and Innovation. London: Anthem Press.
[41] Cohen, W. M. and Levinthal, D. A. (1990) 'Absorptive capacity: a new perspective on learning and innovation', Administrative science quarterly, 35(1); Johnson, B. H. (1992) 'Institutional Learning', in Lundvall,

Other authors have referred to this experimentation and learning process as 'smart specialisation'.[42] However, smart specialisation is most commonly used in connection with a market failure framework, meaning that it is seen as a discovery process for the identification of bottlenecks, failures, and missing links (that is, market-failures or market gaps). Smart specialisation would be more usefully employed in connection to a systemic perspective on innovation policies.

Key to mission-oriented innovation is the exploration of the characteristics of innovation agencies that must be in place so that they can welcome uncertainty and build explorative capacity. Breznitz and Ornston focus on the role of peripheral agencies, arguing that when they become too central and well-funded they lose their flexibility and ability for out of the box thinking.[43] While the importance of flexibility is no doubt important, it is also true that some of the most important innovation agencies in Europe and the US were not so peripheral, as can be seen by DARPA's continued success in recent years. What seems to be more important for these organisations is a degree of political independence. Indeed, Italy's public holding company IRI (the *Istituto per la Ricostruzione Industriale* established in 1933) had its most successful phase before the 1970s when it was public. The key lesson is that it is not about public or private, but what kind of public and what kind of private.

A Networked Entrepreneurial State

An entrepreneurial state is not comprised of one ministry or agency calling the shots top-down, but rather by the set of decentralised interactions between different agencies across the entire innovation chain, in turn interacting with private actors. It is this system that has been at the centre of US competitiveness.[44] This competitiveness is today under potential threat from the US government's cuts to those very agencies.[45]

In *The Entrepreneurial State* these lessons are used to reflect on more general principles, building a market making view of policy.[46] Five key points are emphasised:

- Investment along the entire innovation chain, including demand-side policies.
- Decentralised nature of public mission-oriented organisations (not top-down).
- Risk-taking and investment not only during the downside of the business cycle.
- Long-term strategic finance.

B.-A. (ed.) National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. London: Pinter, pp. 23-44.

[42] Foray, D., David, P. A. and Hall, B. (2009) 'Smart Specialisation. The concept'.

[43] Breznitz, D., and Ornston, D. (2013) "The revolutionary power of peripheral agencies. Explaining radical policy innovation in Finland and Israel." Comparative Political Studies 46(10): 1219-1245.

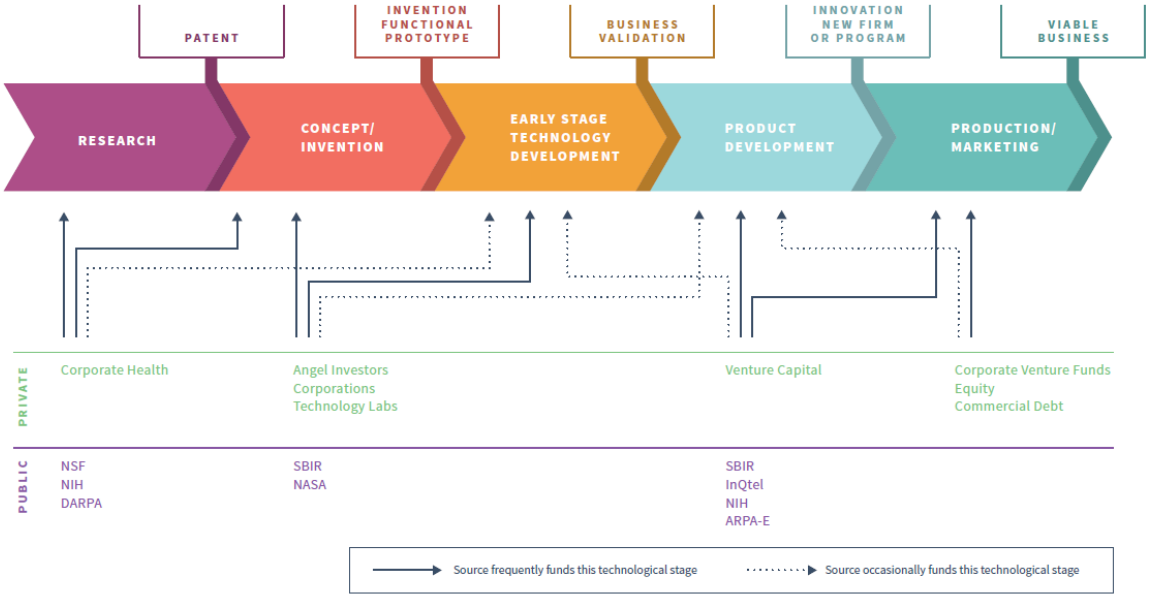
[44] Block, F. L. and Keller, M. R. (eds.) (2011) *State of innovation: the U.S. government's role in technology development*. Boulder, CO: Paradigm Publishers.

[45] Mooney, C. (2017) 'Trump wants to dismantle this energy innovation program. Scientists just found out that it works. *The Washington Post.* Article. Available at: https://www.washingtonpost.com/news/energy-environment/wp/2017/06/13/trump-wants-to-cut-this-energy-innovation-program-scientists-just-found-that-its-working/?utm_term=.6142ef9bf16a.

[46] Mazzucato, M. (2013) *The Entrepreneurial State*.

- Equitable distribution of risk and rewards.

Figure 2. Mission-oriented Finance along entire innovation chain



Source: Author's insertion of public funding agencies into original figure from Auerswald/Branscomb (2003).[47]

Investment along the entire innovation chain

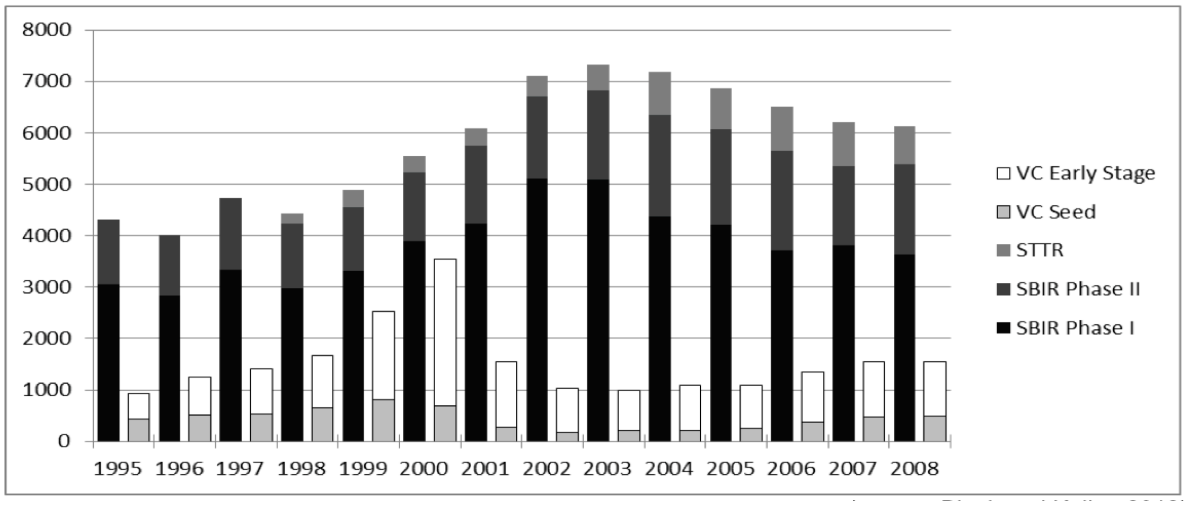
Market failure theory justifies intervention when there are clear market failures, such as when there are positive externalities generated from 'public goods' like basic research. While technological revolutions have always required publicly funded science, often ignored by the market failure framework is the complementary public funds also spent by a network of different institutions further on in the innovation process. In other words, the public sector has been crucial for applied research, as well as for basic research, and for providing early-stage high-risk finance to innovative companies willing to invest. The public sector has historically also been important for the direct creation of markets through procurement policy,[48] and for bold demand policies that have allowed new technologies to diffuse.[49] Thus, Perez argues that, for example, without the policies that led to the growth of suburbs in the US, mass production would not have had the effect it did across the economy.

Figure 2 indicates some of the key public agencies in the US innovation landscape, including the National Institutes of Health (NIH), NASA, the Defense Advanced Research Projects Agency (DARPA), the sister organisation in the department of energy (ARPA-E), the Small Business Innovation Research Programme (SBIR), and the National Science Foundation (NSF), which have been active

[47] Auerswald , P. E. and Branscomb, L. M. (2003) 'Valleys of Death and Darwinian Seas: Financing the Invention of Innovation Transition in the United States'. Journal of Technology Transfer 28, nos. 3–4: 227–39.
[48] Edler, J. & Georghiou, L. (2007) 'Public Procurement and Innovation: Resurrecting the Demand Side', Research Policy, 36(7), 949–63.
[49] Perez, C. (2013) "Financial bubbles, crises and the role of government in unleashing golden ages" in Pyka, A. and Burghof, H-P. (eds.) *Innovation and Finance.* Routledge: London.

across the entire innovation chain. Such organisations have been 'mission driven' in that they have directed their actions based on the need to solve big problems, and in the process actively created new technological landscapes, rather than just fix existing ones.[50] Downstream investments included the use of procurement policy to help create markets for small companies, through the public Small Business Innovation Research (SBIR) scheme, which historically has provided more early stage, high-risk finance to small and medium sized companies than private venture capital has,[51] as **Figure 4** shows. And guaranteed government loans are regularly used to pump prime companies, such as the $465 million guaranteed government (DoE) loan received by Tesla to produce the 'Tesla S' car.[52]

Figure 3. Number of SBIR and STTR grants compared to private venture capital.



Source: Keller and Block (2012).

While it is a common perception that it is private venture capital that fund start-ups, evidence shows that most high-growth innovative companies receive their early stage high-risk finance from public sources, such as Yozma in Israel,[53] venture funds in public banks,[54] the SBIR se funds in the US,[55] and the Small Business Research Initiative in the UK.[56] While private venture capital is exit-driven,

[50] Foray, D., Mowery, D. and Nelson, R. R. (2012) "Public R&D and Social Challenges: What Lessons from Mission R&D Programs?".
[51] Block, F. L. and Keller, M. R. (eds.) (2011) *State of innovation: the U.S. government's role in technology development*.
[52] US Department of Energy Loan Programs Office, 'Tesla' (2017) Webpage. Available at: https://energy.gov/lpo/tesla.
[53] Breznitz, D., and Ornston, D. (2013) "The revolutionary power of peripheral agencies";
[54] Mazzucato, M. and Penna, C. (2016b) "Beyond market failures: the market creating and shaping roles of state investment banks", Journal of Economic Policy Reform, 19(4): 305-326.
[55] Block, F. L. and Keller, M. R. (eds.) (2011) *State of innovation: the U.S. government's role in technology development*.
[56] Connell, D. (2014) 'Creating markets for things that don't exist: The Truth About UK Government R&D and How the Success of SBRI Points the Way to a New Innovation Policy to Help Bridge the Valley of Death and Rebalance the UK Economy'. Centre for Business Research, University of Cambridge. Available at: http://www.cc2-live.co.uk/davidconnell/docs/c%20dc-pub.pdf.

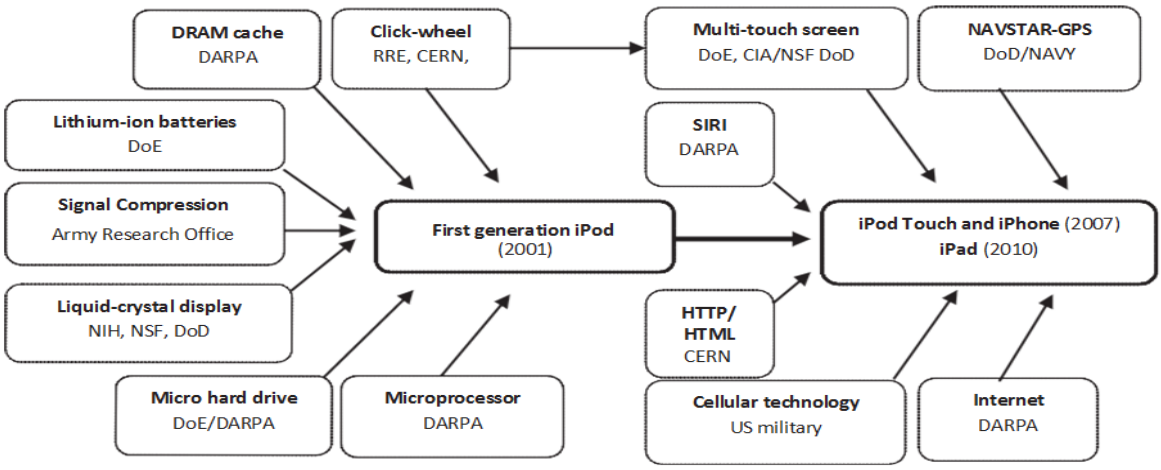
seeking returns within three to five years, these forms of public finance have been less risk-averse and more patient—thus better suited for the needs of innovation. This lesson does not seem to have been learned in various parts of the developed and developing world, where leaders continue to think that attracting venture capital (mainly through tax schemes, such as reductions in capital gains) will foster innovation. If we look to history we can see that venture capital entered industries like biotechnology in the late 1980s, while the high-risk capital intensive investments had been done by the US government in the 1950s and 1960s.[57]

In all these cases, government intervention was not driven by market failure. Instead, it deliberately targeted industries with public venture capital assistance. Similarly, in today's renewable energy sector, entrepreneurs like Elon Musk have received guaranteed loans from the US Department of Energy, with the LA Times estimating that his three companies (Tesla, Space X and Solar City) have together received around $5 billion in public support.[58]

Decentralised network of mission-oriented agencies

Crucial to this public funding was the nature of the organisations themselves, what Block and Keller have called a *developmental network state*.[59] Better understanding of the distribution of public agencies, their positioning across the innovation chain, and the balance between directive and bottom-up interactions is a key area for future study.

Figure 4. Publicly funded technology in 'smart' phones



Source: Mazzucato (2013a), p.109, Fig. 13.

[57] Vallas, S. P., Kleinman, D. L. and Biscotti, D. (2011) "Political Structures and the Making of U.S. Biotechnologynology." In: Block, D and Keller, M. R. (eds,) State of Innovation: The U.S. Government's Role in Technology Development. Boulder CO: Paradigm.
[58] Hirsch, J. (2015) 'Elon Musk's growing empire is fueled by $4.9 billion in government subsidies'. *Los Angeles Times*. Available at: http://www.latimes.com/business/la-fi-hy-musk-subsidies-20150531-story.html.
[59] Block, F. L. and Keller, M. R. (eds.) (2011) State of innovation: the U.S. government's role in technology development.

In the case of IT, as **Figure 4** illustrates, the technologies that have made Apple's i-products (iPhone, iPad, etc) 'smart' were initially funded by different public-sector institutions: the Internet by the Defense Activated Research Projects Agency (DARPA); global positioning system (GPS) by the US Navy; touchscreen display by the Central Intelligence Agency (CIA); and the voice-activated personal assistant Siri by DARPA.[60]

Key for our purposes is the fact most of the agencies developing the technologies were mission driven: they did not see their job as fixing markets but as actively creating them. Mission statements can help direct public funds in ways that are more targeted than, say, simply helping all SMEs. Examples of mission statements include:

- **NASA**: to *"[d]rive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth*." (NASA 2014 Strategic Plan).
- **DARPA:** "*Creating breakthrough technologies for national security is the mission of the Defense Advanced Research Projects Agency".*
- **NIH**: to *"seek fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to enhance health, lengthen life, and reduce illness and disability".*

Mission-oriented agencies are potentially better able to attract top talent as it is an 'honour' to work for them. By actively creating new areas of growth they are also potentially able to 'crowd in' business investment by increasing business expectations about where future growth opportunities might lie.[61]

Risk taking across the business cycle

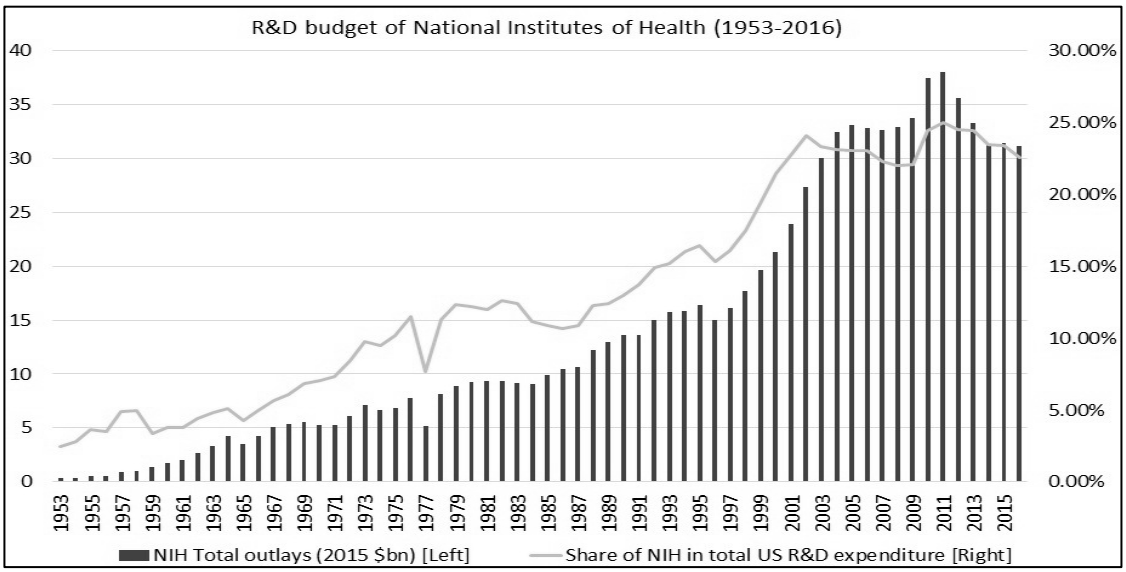
Market failure theory foresees the need to also fix 'coordination failures' such as pro-cyclical spending in the business sector. Indeed, much of Keynesian economics primarily considers the role of the state as essential in recessions (for its counter-cyclical role to prevent depressions), ignoring the fact that public financing of innovation has been just as important in boom periods. Evidence shows that mission-oriented agencies have been critical across the business cycle, not only to stimulate investment during recessions. The National Institutes of Health (NIH) have spent billions on health R&D, stimulating what later became the biotechnology revolution in both periods of boom and bust.

From 1936 to 2016, cumulative R&D expenditure by NIH has amounted to more than $900 billion (in 2015 dollars), and since 2004 has exceeded $30 billion per year (**Figure 5**). Perhaps unsurprisingly, research shows that around 75 percent of the most innovative drugs on the market today (the so-called 'new molecular' entities with priority rating) owe much of their funding to the NIH (Angell, 2004). Moreover, the share of R&D expenditure taken by NIH in total US federal outlays in R&D has increased year on year over the past 50 years. This suggests that the surge in absolute NIH-related R&D expenditure cannot simply be conceived as resulting from a generalised and proportional

[60] Mazzucato, M. (2013) The Entrepreneurial State.
[61] Mazzucato, M. and Penna, C. C. R. (eds.) (2015a) Mission-Oriented Finance for Innovation: New Ideas for Investment-Led Growth. London: Policy Network/Rowman & Littlefield.

increase in total R&D expenditure by the government during downturns, or to simply level the playing field. Instead, it appears as a deliberate and targeted choice on where to direct public R&D funding.

Figure 5. R&D budget of National Institutes of Health (1953-2016, in 2015 dollars).



Source: National Institutes of Health Office of Budget

Mission-oriented financing as a direct form of investment

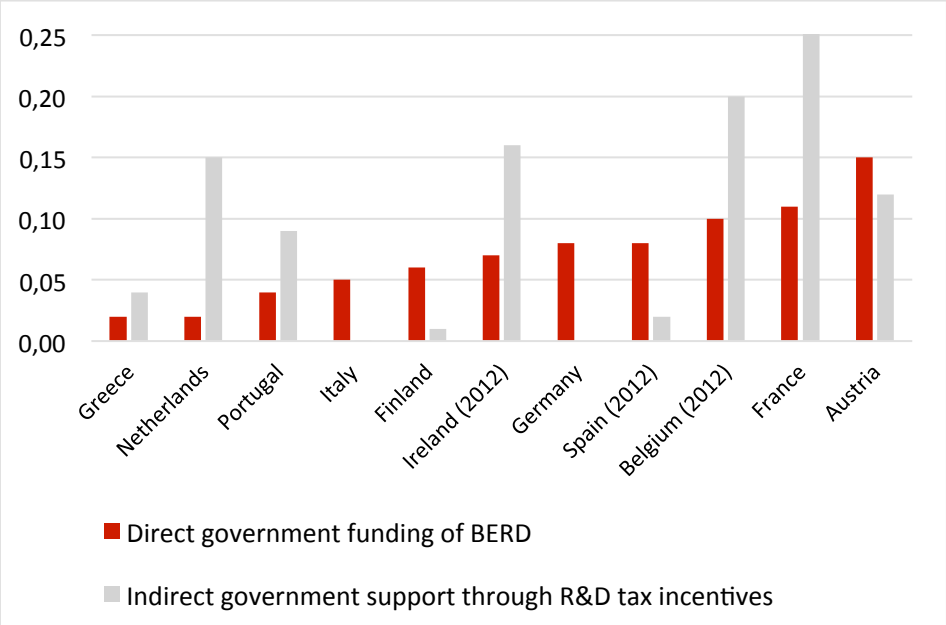
Mission-oriented investments are 'direct'. Tax incentives are 'indirect'. Direct investments that create new technological and industrial landscapes tend to crowd-in private investment more than indirect tax incentives. A typical and straightforward way of assessing the government support for innovation is to look at its contribution towards financing R&D activities broken down between direct and indirect mechanisms. As **Figure 6** shows, countries in the Eurozone present different patterns in this regard for financing Business Expenditure on R&D (BERD).

Relative to their GDP, the governments of Greece and Portugal spend between half and one third in direct funding of BERD compared to Austria, France and Germany. At the same time, Portugal and Greece dedicate a larger amount of resources to tax incentives for business R&D, such as allowances and credits, or in other forms of advantageous tax treatment of business R&D expenditure. However, in contexts where technological opportunities are lacking in the first place, due for instance to the lack of systemic and mission-oriented industrial and innovation policies, those incentives might be well used to avoid taxation and increase profits, without additional investment in R&D. It is well documented – for instance in Canadian and Dutch studies[62] [63]– that such indirect

[62] Dagenais, M, Mohnen, P. and Therrien, P., (1997) Do Canadian Firms Respond to Fiscal Incentives to Research and Development?. CIRANO, Scientific Series, 97s-34, October 1997, GREQAM document de travail 97B05.

measures of R&D financing often do not make things happen that would not have happened anyway. Indeed, countries with higher indirect mechanisms (relative to direct) tend to have lower business spending on R&D (BERD).

Figure 6: Direct government funding of BERD and indirect government support for BERD as a percentage of GDP (2013)



Source: Authors' elaboration on OECD data
Notes: Indirect figures unavailable for Germany and Italy.

Another example of an indirect innovation policy that does not create additionality is that of the so-called 'patent box', introduced in the UK in 2013 and in Italy in 2015, following the examples of the Netherlands, Belgium and Spain. The patent box gives a tax relief on profits arising from registering a patent, which is itself a monopoly reward that seeks to defend the appropriability gain of the innovator from potential competitors. There is no reason to give an additional tax relief on that monopolistic rent: the patent entitlement is already the reward. The patent box is simply a second, additional compensation given to an activity that has already happened.[64] It would be much more effective to target spending on initiatives that encourage new waves of innovation, rather than the profits that are produced from past innovations.

If governments want to implement innovation policies that generate real additionality, this suggests that rather than enhance the profitability of existing innovations, they should act as an investor of first resort in new ones, absorbing the high degree of uncertainty during early stages of innovation and possibly welcoming failures when they happens.

[63] Lokshin, B. and Mohnen, P. (2013) Do R&D tax incentives lead to higher wages for R&D workers? Evidence from the Netherlands, *Research Policy*, Vol 42, Issue 3, pp823-830 http://dx.doi.org/10.1016/j.respol.2012.12.004.

[64] Griffith, R., Miller, H., and O'Connell, M. (2010) Corporate Taxes and Intellectual Property: Simulating the Effect of Patent Boxes, IFS Briefing Note 112, Institute for Fiscal Studies.

There are nonetheless positive examples in this respect. In the case of Germany, which ranks among the highest countries in the EU in every single innovation statistic, its success in recent decades can be ascribed to the combination of a directional "High-Tech" industrial strategy[65] and targeted mission-oriented programmes, such as the *Energiewende* for energy transition.[66] These policies are directly financed by the government, either through its federal budget – state aid directed to environmental protection and energy saving has increased by almost €25 billion between 2013 and 2014, the great bulk of it through grants[67] – or through the KfW, Germany's public investment bank, whose investments in energy efficiency projects in 2015 alone amounted to almost €15 billion.[68] On the contrary, industrial policy programmes which remain reliant on R&D tax credits and other indirect incentives will most likely not reinvigorate the "spontaneous urge to action rather than inaction", namely the endogenous "animal spirits" of the private sector to innovate.

Patient finance: the importance of public finance

It is precisely due to the short-term nature of private finance that the role of public finance is so important in nurturing the parts of the innovation chain subject to long lead times and high uncertainty. While in some countries this has occurred through public agencies, such as DARPA and NIH, in others, patient finance has been provided through publicly-owned development banks, otherwise known as state investment banks.

State investment banks (SIBs) have their historical roots in the monetary agreements of Bretton Woods and the reconstruction plans for Europe following the Second World War. The idea was to create an institution that promoted financial stability through a permanent flow of finance to fund the reconstruction plan and unleash agricultural production potential, thus preventing the deleterious effects that speculative private finance could have on post-war economic recovery.[69] Following this rationale, the International Bank for Reconstruction and Development (IBRD) was created, providing its first loan to France in 1947.[70] Other national development banks soon followed, such as KfW in Germany, with the aim of channelling international and national funds to the promotion of long-term growth, infrastructure and modern industry. While in industrialised countries these institutions focused on niche areas (such as aiding specific sectors), in developing

[65] BMBF (2014) "The new High-Tech Strategy: Innovations for Germany". Bundesministerium für Bildung und Forschung / Federal Ministry of Education and Research (BMBF).
[66] BWMi (2015) "Making a success of the energy transition". Bundesministeriums für Wirtschaft und Energie / Federal Ministry for Economic Affairs and Energy (BWMi).
[67] European Commission (2016) "State Aid Scoreboard 2016". Available at: European Commission, scoreboard,index.
[68] KfW (2015) "2015 Financial Report". Kreditanstalt für Wiederaufbau, Frankfurt am Main, Germany. Available at: https://www.kfw.de/PDF/Download-Center/Finanzpublikationen/PDF-Dokumente-Berichte-etc /3_Finanzberichte/KfW-Finanzbericht-2015-E.pdf.

[69] World Bank (2015) History. Available at: http://go.worldbank.org/65Y36GNQB0. Accessed 15 December 2015.
[70] M.Schröder *et al*., *op. cit*.

countries SIBs such as the Brazilian BNDES initially promoted a catching-up agenda, with heavy investments in infrastructure.[71]

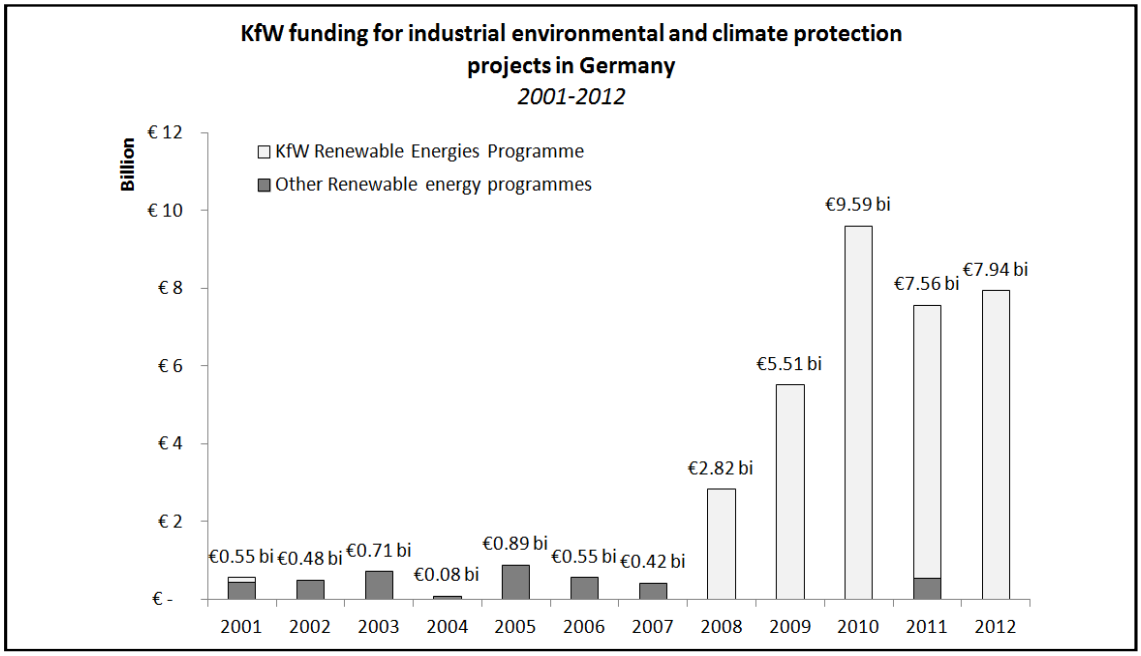
In subsequent decades, SIBs diversified their operations and focus. In the mid-1950s, KfW assumed the responsibility to provide finance for environmental protection and small and medium-sized enterprises (SMEs), roles that were intensified in the 1970s when it also began to target energy efficiency and innovation.[72] Other development banks followed suit. BNDES, for instance, created new credit lines for SMEs in the 1980s, and in the following decade began to experiment with financing programmes targeted at high-tech firms and innovation development.[73] By the 2000s, China Development Bank (CDB) was one of the most active SIBs, investing in regional economic development and industrial catching-up, supporting and nurturing new ventures and innovation development, and, later in the decade, targeting finance to projects aimed at 'green growth'.[74] After the outbreak of the global financial crisis in 2007, SIBs across the world significantly promoted counter-cyclical credit, increasing their loan portfolio by 36 percent on average between 2007 and 2009, with some increasing their loans by more than 100 percent.[75]

While the traditional functions of state investment banks were in infrastructure investment and counter-cyclical lending during recession when private banks restrained credit (thus playing a classic Keynesian role), they have, over time, become more active as key players in the innovation system. They have provided the patient capital for innovative firms, and also focused on modern societal challenges with technological 'missions'. For example, SIBs have notably filled the vacuum left behind by private commercial banks since the financial crisis, more than trebling their investments in clean energy projects between 2007 and 2012.[76] [77] A recent report by Bloomberg New Energy Finance finds that in 2013 state investment banks were the largest funders of the deployment and diffusion phase of renewable energy, outpacing investment from the private sector.[78] The four most active banks are (in order): the Chinese Development Bank, the German KfW, the European Investment Bank (EIB), and the Brazilian BNDES. Examples of 'mission-oriented' investments include: the European Investment Bank's €14.7 billion commitment to sustainable city projects in Europe,[79] the efforts of KfW to support Germany's *Energiewende* policies through the greening and

[71] Torres Filho, E. T. and Costa, F. N. D. (2012) 'BNDES E O Financiamento Do Desenvolvimento', Economia e Sociedade, vol. 21, pp. 975–1009.
[72] KfW, 'Annual Report 2008', Frankfurt am Main (2009) KfW Group.
[73] Branco, C.E. (1994) 'Apoio às Pequenas e Médias Empresas de Base Tecnológica: A Experiência do Contec', Revista do BNDES, Vol. 1, pp. 129–142; F.L.D. SoUS (ed.) (2012) 'Bndes 60 Anos: Perspectivas Setoriais', Rio de Janeiro: BNDES.
[74] Sanderson, H. and Forsythe, M. (2013) 'China's Superbank: Debt, Oil and Influence – How China Development Bank is Rewriting the Rules of Finance', Singapore: John Wiley & Sons.
[75] Luna-Martinez, J. and L.Vicente, L. (2012) 'Global Survey of Development Banks', World Bank Policy Research Working Paper.
[76] Mazzucato, M. and Penna, C. (2016b) "Beyond market failures: the market creating and shaping roles of state investment banks", *Journal of Economic Policy Reform*, 19(4): 305-326.
[77] L.S.Fried, S. Shukla and S. Sawyer (eds.) (2012) 'Global Wind Report: Annual Market Update 2011', Global Wind Energy Council, March 2012.
[78] Louw, A. (2012) 'Development banks: less for green in 2013?' Renewables Research note, 2012, Bloomberg New Energy Finance.
[79] Griffith-Jones and J.Tyson, (2012) 'The European Investment Bank and Its Role in Regional Development and Integration', in: The Transformations of the International Financial System, M.A.Cintra and K.D.R.Gomes (eds.), Brasília: IPEA.

modernisation of German industries and infrastructures, China Development Bank's investments in renewable energies, and the technology fund put in place by BNDES to channel resources toward selected technologies in Brazil (FUNTEC).[80] **Figure 7** below, for example, illustrates the way in which KfW has not only played a classical Keynesian counter-cyclical role, but also directed that funding towards 'climate financing'.

Figure 7: KfW: Financing the Green Mission



Risks and rewards

Considering these roles more explicitly allows us to reflect on the degree to which the division of labour in risk-taking is matched or not by a division of rewards, which one would expect if there is a *risk-return* relationship. It also helps us to better understand whether the eco-system is creating the right incentives. Is it the case that because some actors are putting in a lot, other actors have been given fewer incentives to do their share?

Innovation is highly uncertain: for every success (eg the Internet) there are many failures. High failure rates are just as common upstream (in R&D projects) as downstream in public financing of firms. A better understanding of how portfolios are managed in mission-oriented agencies is therefore important —such as in Yozma in Israel, Sitra in Finland, or SBIR in the US. This requires a lead investor understanding of public funds that goes beyond the need to correct for asymmetric information. It is not a matter of lacking information, but rather the willingness to engage in big thinking and its underlying uncertainty.

[80] BNDES 2012. 'Apoio À Inovação' (2012) Rio de Janeiro: BNDES.

Having a vision about the direction in which to drive an economy requires direct and indirect investment in particular areas, not just creating the horizontal (framework) conditions for change. Crucial choices must be made, the fruits of which will create some winners, but also many losers. For example, the US Department of Energy recently provided guaranteed loans to two green-tech companies: Solyndra ($500 million) and Tesla Motors ($465 million). While the latter is often glorified as a success story, the former failed miserably and became the latest example in the media of a government being inefficient and unable to pick winners.[81] However, any venture capitalist will admit that for every winning investment (such as Tesla) there are many losses (such as Solyndra).

In making its downstream investments, therefore, governments can learn from portfolio strategies of venture capitalists, structuring investments across a risk space so that lower risk investments can help to cover the higher risk ones. In other words, if the public sector is expected to compensate for the lack of private venture capital (VC) money going to early-stage innovation, it should at least be able to benefit from the wins, as private VC does. Otherwise, the funding for such investments cannot be secured. As argued in Mazzucato and Wray, even if money could be secured for public investments endogenously (through money creation), it is desirable to allow the state to reap some of the rewards from its investments for a number of other reasons.[82] Matching this type of spending with the corresponding return would provide a measure of efficiency, holding policymakers accountable; government net spending has limits dictated by the real resource capacity of the economy; and voters will be more willing to accept the (inevitable) failures if they see that those are compensated by important successes.

The public sector can use a number of return-generating mechanisms for its investments, including retaining equity or royalties, retaining a golden share of the IPR, using income-contingent loans, or capping the prices (which the tax payer pays) of those products that emanate, as drugs do, from public funds.[83] Before exploring the details of each mechanism, however, it is crucial for the policy framework to allow the question to be asked. In a market-shaping framework, does government have the right to retain equity more than in a market failure framework? Are taxes currently bringing back enough return to government budgets to fund high-risk investments that will probably fail?

Learning the right lessons from The Entrepreneurial State

"Public values are those providing normative consensus about (1) the rights, benefits, and prerogatives to which citizens should (and should not) be entitled; (2) the obligations of citizens to society, the state, and one another; (3) and the principles on which governments and policies should be based."

Barry Bozeman, 2007[84]

[81] Wood, R. (2012) 'Fallen Solyndra Won Bankruptcy Battle but Faces Tax War'. Forbes, 11 June. Available at: http://www.forbes.com/sites/robertwood/2012/11/06/fallen-solyndra-won-bankruptcy-battle-butfaces-tax-war/.
[82] Mazzucato, M. and Wray, L. R. (2015) "Financing the Capital Development of the Economy: A Keynes-Schumpeter-Minsky Synthesis", Working Paper, n. 837, Levy Economics Institute. Available at: http://www.levyinstitute.org/pubs/wp_837.pdf.
[83] Mazzucato, M. (2013) The Entrepreneurial State, Anthem.
[84] Bozeman, B. (2007) Public values and public interest: counterbalancing economic individualism. Georgetown University Press

Weiss places caution on the role of US public agencies in fostering innovation.[85] She highlights the strong military and security interests that have shaped US innovation policy, and the way that corporate interests have taken advantage of these.

It is right to be cautious. And it is precisely a wide debate about what it means to have mission-oriented thinking that can allow active public policy in innovation to be re-directed towards societal needs (and the wicked problems that connect health, sustainability, nutrition, education, and poverty) and not only military and security needs. By creating a more symbiotic relationship between the public and private sectors—focused on targets of 'additionality'— the possibility of particular sectors to capture innovation policy is reduced, as is the possibility that particular companies lobby for policies (including tax policies) which increase profits but do not help the generation of public value.

Understanding how the definition of missions can be opened up to a wider group of stakeholders, including movements in civil society, is a key area of interest. Indeed, it was to a large extent the green movement in Germany (including but not restricted to the Green Party) that led to a slow cumulative interest in society about tackling green missions, which was subsequently represented in the *Energiewende* agenda.

Understanding more democratic processes through which missions are defined and targeted is tied to rethinking the notion of public value. Indeed, part of building a market shaping and creating framework that can guide mission-oriented thinking beyond the market failure framework involves rethinking *public value* beyond the notion of the "public good". Too often the public good concept has been used to limit and constrain the activities of public actors, creating a static distinction between those activities for business and those for policy. This means that ambitious policies—daring to reimagine the market rather than just fixing the public good problem-- have then been accused of 'crowding out' private activity, whether the accused are innovation agencies, public banks or the BBC.[86]

But similarly, achieving public value cannot be the work only of the public sector, hence opening up this process to include a wider set of stakeholders – involved in the definition of missions as well as the serendipitous process of how to achieve them – will be an exciting new area of analysis linked to 21st century innovation policy targeting grand challenges.

Implementing mission-oriented policies

The historical examples and future potential of mission-oriented policy approaches have led to growing interest from around the world. But questions remain about how to apply the lessons of history to the challenges of today.

[85] Weiss, L. (2014) America Inc.?: Innovation and enterprise in the national security state. Ithaca; London: Cornell University Press.

[86] Mazzucato, M. and O'Donovan, C. (2016) "The BBC as market shaper and creator" in Rethinking the BBC: Public media in the 21st Century, Seth-Smith, N., *et. al*. (eds.), Commonwealth Publishing. Available at: http://commonwealth-publishing.com/shop/rethinking-the-bbc-public-media-in-the-21st-century/.

When policy-makers have acted in this way in the past, they have had to work outside established policy frameworks. What is needed is a policy framework they can work within: a new framework that can be used to justify, guide and evaluate mission-oriented innovation policies.

The challenge is to develop this new framework, along with the analytical tools, related policy apparatus, and new organisational capabilities to enable policy-makers to apply it in practice – in relation to different types of challenges and in different spatial or other contexts. To conclude this scoping paper, some general principles are listed below.

Linking innovation policy to the systemic characteristics of innovation

Innovation policy must build on the key characteristics of how innovation comes about: it is uncertain, cumulative and collective.[87]

- **Uncertainty** means that agents concerned with innovation cannot calculate in advance the odds of success or failure – that is, results are unknown – and therefore in order to succeed will have also to accept occasional failures and detours from planned routes.
- **Cumulative** means that agents need to be patient and act strategically to accumulate competences and capabilities (learn) with a view to the long term.
- **Collective** means that all agents need to work together and thus bear certain degrees of risk; they are therefore entitled to also share the rewards.

Policies based on a mission-oriented perspective are systemic, employing but going beyond science-push instruments and horizontal instruments. Mission-oriented policies employ the array of financial and non-financial instruments to promote the accomplishment of a mission across many different sectors, setting concrete directions for the economy, and deploying the necessary network of relevant public and private agents.

A *broad perspective* on the national system of innovation identifies four subsystems: (i) public policy and public funding; (ii) research and education; (ii) production and innovation; and (iv) private finance and private funding. While all subsystems are theoretically of strategic importance, the subsystem of public policy and funding has traditionally led the process of socio-economic development and technical change.

In order to stimulate the innovation process by shaping and creating technologies, sectors and markets, new relationships must be developed and more trust must be created. The state must galvanise the interests of relevant actors and organise itself so that it has the 'intelligence' to think big and formulate bold policies that also create a sense of ownership amongst diverse public, private and academic stakeholders. It is also crucial to be able to implement the policies by coordinating the efforts of this network of stakeholders through the state's convening power, brokering of trust relationships, and the use of targeted policy instruments.

[87] Lazonick, W. and Mazzucato, M. (2013) 'The risk-reward nexus in the innovation-inequality relationship: who takes the risks? Who gets the rewards?', Industrial and Corporate Change, 22(4), pp. 1093-1128.

To fulfil a mission, a country requires an entrepreneurial state. This concept encapsulates the risk-taking role adopted by the state in the few countries that have managed to achieve innovation-led growth. It is through mission-oriented policy initiatives and investments across the entire innovation process – from basic research to early-stage seed financing of companies – that the state is able to have a greater impact on economic development.

Different types of capacity building

Different types of capacity building are central to mission-oriented policies:

- **Scientific-technological capacity:** an appropriate scientific and technological knowledge base in the subsystem of education and research;
- **Demand capacity:** latent or effective (public or private) market demand, in terms of both purchasing power and need;
- **Productive capacity:** an appropriate business base (for example, existing firms or entrepreneurs willing to take risks to establish an innovative firm) in the subsystem of production and innovation;
- **State capacity:** appropriate knowledge inside the public organisations formulating and executing the policies about the problem and solution being targeted and/or knowledge about who-knows-what-and-how;
- **Policy capacity**: appropriate supply-side and demand-side policy instruments (strategically deployed), supported by complementary policies;
- **Foresight capacity:** a fine-tuned diagnosis of the problem and solution, including an analysis of the current situation and future prospects for targeted technologies and sectors, formulated in terms of a well-defined mission and vision.

Successful mission-oriented policy experiments require all six factors in place. They require a more dynamic framing of key questions: less about picking or not picking, and more about the institutional and organisational capacity of forming broadly defined directions, through strategic deliberation. Less about static cost-benefit metrics which so often result in accusations of 'crowding out' and more about dynamic assessment criteria that can nurture and evaluate market shaping processes and capture the spill-overs that are created across sectors.

The way forward: a practical approach to implementing mission-oriented innovation policies

We opened this paper with the observation that governments are increasingly seeking economic growth that is smart (innovation-led), inclusive and sustainable. We need to see this in the context of grand social challenges such as tackling climate change, improving public health and wellbeing, and adjusting to demographic changes.

Mission-oriented innovation policy has a major part to play in delivering better quality growth while addressing grand challenges, but the changes in mind-set, theoretical frameworks, institutional capacities and policies required are by no means trivial. So what is the practical way forward?

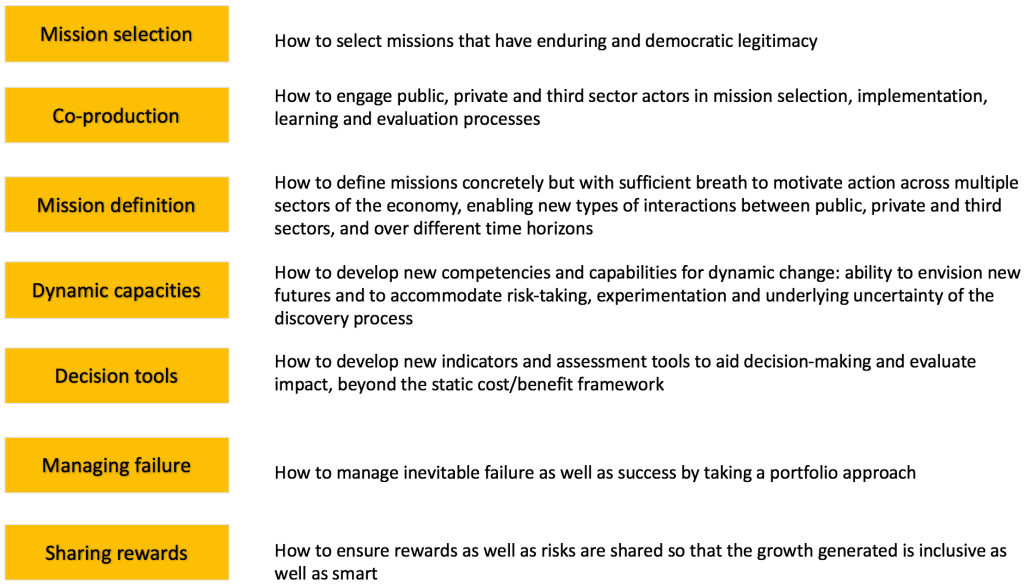
In this respect, four key questions—denoted by the acronym R-O-A-R—can guide the process of developing the new framework to justify, guide and evaluate mission-oriented innovation policies:[88]

- **Routes and directions**: how to use policy to actively set a direction of change; how to foster more dynamic (bottom-up) debates about possible directions to ensure enduring democratic legitimacy; and how to choose and define particular missions concretely, but with sufficient breadth to motivate action across different sectors of the economy.
- **Organisations**: how to build decentralised networks of explorative public organisations that can learn-by-doing and welcome trial and error, with the confidence and capability to lead and form dynamic partnerships with private and third sector partners; how to manage and evaluate progress, learning and adaptation; and how to use a portfolio approach to balance inevitable failure with success.
- **Assessment**: how to evaluate the dynamic impact of public sector market-creating investments, going beyond the static ideas embodied in cost/benefit analysis and ideas of 'crowding in' and 'crowding out' based on a richer conception of public value creation'; how to develop new indicators and assessment tools to aid decision-making.
- **Risks and rewards**: how to form new deals between public and private sectors so that rewards as well as risks are shared.

These questions provide a starting point for the new categories of thought that are needed, with many more questions following in relation to application in particular contexts.

Figure 7 below can be used to reflect on the practical steps that might be useful for mission-oriented organisations.

Figure 7: Practical steps for mission-oriented organisations



[88] These questions are developed in: Mazzucato, M. (2016a) "From Market Fixing to Market-Creating: A new framework for innovation policy", Special Issue of *Industry and Innovation:* "Innovation Policy – can it make a difference?", 23 (2).

Mission-oriented innovation policy is far from being a step into the unknown. As set out in this paper, there is substantial theory, evidence, case studies and experience accumulated over many decades of successful practice. It is also important to understand the challenges associated with gathering the necessary political commitment and public legitimacy behind such ambitious policies.

To reap the substantial benefits from this approach, what is needed is to abandon the ideology that often informs, and misinforms, the role that the state can play in the economy. Public, private and third sector actors can work together in new ways to co-create and shape the markets of the future. We can learn from practical policy experiences to foster a more coherent and cohesive framework across sectors, institutions and nations. Only in this way can investment led growth help address not only the growth problem but help solve the wicked 21st century challenges ahead.

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MISSIONS

Mission-Oriented Research & Innovation in the European Union[89]

A problem-solving approach to fuel innovation-led growth

Mariana Mazzucato

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INTRODUCTION

Why Europe needs missions

The ability of innovation to spur economic growth has long been recognised. Less recognised is the fact that innovation has not only a rate but also a *direction*. By harnessing the directionality of innovation, we also harness the power of research and innovation to achieve wider social and policy aims as well as economic goals. Therefore, we can have innovation-led growth that is also more sustainable and equitable.

Finding ways to steer economic growth, and the European policy agenda, is difficult but necessary. Missions are a powerful tool to do this. They can provide the means to focus our research, innovation and investments on solving critical problems, while also spurring growth, jobs and resulting in positive spillovers across many sectors. Critically, by spearheading public research and innovation investments in new strategic areas that have the possibility to bring together different actors (public, private and third sector) and spurring collaboration across different sectors (e.g. from transport to digital to nutrition) it is possible to awaken private sector investment that continues to lag. Indeed, what drives private investment is the perception of future growth opportunities. Missions help define those opportunities in ambitious ways.

Mission-oriented policies can be defined as systemic public policies that draw on frontier knowledge to attain specific goals or "big science deployed to meet big problems"[90]. Missions provide a solution, an opportunity, and an approach to address the numerous challenges that people face in their daily lives. Whether that be to have clean air to breathe in congested cities, to live a healthy and independent life at all ages, to have access to digital technologies that improve public services, or to have better and cheaper treatment of diseases like cancer or obesity that continue to affect billions of people across the globe. To engage research and innovation in meeting such challenges, a clear direction must be given, while also enabling bottom-up solutions. The debate about directionality should involve a wide array of stakeholders, each contributing to the key questions: What are the key challenges facing society; How can concrete missions help solve those challenges; How can the missions be best designed to enable participation across different actors, bottom-up experimentation and system-wide innovation?

Europe's mission potential

Societal challenges are complex. More complex than going to the moon, which was mainly a technical feat. To solve them requires attention to the ways in which socio-economic issues interact with politics and technology, to the need for smart regulation, and to the critical feedback processes that take place across the entire innovation chain. It also requires stronger civic engagement. Importantly, such challenges cannot be solved by any single European country, no matter how large it may be. Only at the level of the European Union, with its long experience of operating within a multilevel governance system, can we achieve the scale and diversity of talent and ideas to make real progress.

[90] Ergas, H. (1987) 'Does technology policy matter?', in Guile, B.R. and Brooks H. (eds.) Technology and global industry: Companies and nations in the world economy, Washington DC: National Academies Press, pp. 191-245.

The sheer complexity and specialisation of science today means that attitudes of openness and collaboration are not a nice complement, but rather a critical factor for success. European Member States are at different levels of economic development, with some having invested much less than others in the key pillars of innovation: education and research. Nevertheless, in every single country there are areas of excellence and expertise that could prove to be the critical factor to solve the challenges of today. Missions are primarily a way to orchestrate the rich diversity of talent and expertise that today lies mostly fragmented or untapped across Europe. They are also a way to harness the recognition that such expertise is itself an outcome of investment and innovation.

A mission-driven approach can be critical for European competitiveness. Other major players in the global economy, like China or the United States, have innovation systems that are more centralised or focused on a reduced number of key clusters. Europe, on the other hand, is both more fragmented – which can be a negative in terms of gaining scale – and more diverse –, which creates a messier but also potentially more creative environment. To capitalise on this asset, Europe needs to take the next step and take advantage of its unique nature as a common market of diverse economies. In addition to strengthening regional research and innovation capacities, Europe also needs European Union wide efforts to connect policies and grand challenges. What the mission approach can add to the next European Framework Programme for Research and Innovation is a new lens to help steer investment towards tackling challenges but in a more focussed, problem-solving manner. Europe's unique multilevel governance system is highly suitable for mission-oriented policies: member states and regions can experiment within larger EU-wide missions.

This is not about a box ticking exercise to solve one problem after another. This is a way to steer economic growth in ways that are more meaningful. It is also about designing and implementing policies in a way that more strongly links them to delivery and results. Indeed, in a historical period in which business investment is lagging and belief in liberal democracy seems to be floundering, missions also provide more excitement about where economic growth opportunities might lie and how to reinvigorate democratic processes around economic policies. By setting missions that require different sectors to work together, it is possible to create instruments that reward those businesses that are willing and able to co-invest alongside European and Member State public investments. It is not about static subsidies but about dynamic co-investment along the entire innovation chain. It is about thinking how to concretely share not only the risks of innovation but also how to best share the rewards in ways that benefit society the most.

THE MAN ON THE MOON MISSION

The Apollo 'Man on the Moon' mission expressed by President John F. Kennedy in 1961[91] was a geo-political and technological mission. It set a clear and ambitious objective: put a man on the moon and bring him back safely. There was also a concrete timeline – get there before the end of the decade (1960s).

The Apollo mission required investments and innovation not just in aerospace but also across multiple sectors (food, medicine, computation, materials, biology, microbiology, geology, electronics, and communications). Without new materials, for example, the mission would not have worked. It inspired children to dream about becoming astronauts; reinvigorating STEM subjects in schools; required researchers from various disciplines and sectors to cooperate to solve problems in a bottom-up manner; stimulated new types of risk-taking in many different sub-projects, of which

[91] European Commission (2018) Mission-oriented R&I policies: Case Study Report Apollo Project (US). Available at: http://europa.eu/!Fj47uu.

many, of course, failed.

Apollo resulted in success - when Neil Armstrong was the first man to set his foot on the moon on 20 July 1969 – but it also led to many unexpected spinoffs that would not have emerged without this massive engagement with a science and innovation led objective. Indeed many of these spinoffs — such as the integrated circuit — would have arisen even if Armstrong had never set foot on the moon. The process of systemic cross-disciplinary, cross-sectoral, and cross-actor innovation that Apollo stimulated was every bit as important as the mission itself.

Apollo was inspirational, and much can be learned about the importance of setting clear goals, while allowing bottom-up experimentation to contribute to the overall success, but when we think of selecting EU missions today it is necessary to frame missions with a clearer societal relevance. While a purely technological mission may be appropriate for an innovation agency (e.g. in the case of space this would include NASA or ESA), at the EU level, we must be more ambitious in making the link to societal impact. For example, it would be useful to consider how innovation in space, particularly in new satellites and surveillance technology, could be used to curtail the number of deaths of immigrants crossing the Mediterranean. This would require collaboration between sectors as different as space, security services, marine technology, shipping, and immigration services.

Change begins at home

Because "change begins at home", missions first and foremost have to tap into the rich stock and flow of high quality science and innovation that is already being funded under different European programmes. Horizon 2020 is one of the largest global funds for science and innovation. It is certainly the largest fund under a single political authority, with the added strength of being fully open to the world. Unlike most other public funds, it combines science and innovation under the same umbrella, spanning from curiosity-driven frontier science to support for start-ups and partnerships with industry. This means that missions can provide policy makers for the first time a privileged view over the different elements of this vast and complex programme.

European research and innovation missions will thus have as a core strength and differentiating factor privileged direct access to the pipeline of one of the most comprehensive science and innovation programmes in the world. Under a given mission, it will be possible both to identify some of the most advanced, relevant scientific projects funded by the European Research Council and mobilise them to contribute to a mission; and at the same time to use the future European Innovation Council to look into what the most advanced start-ups are doing and how they can support a given mission. Thus, missions will be a way to combine different and diverse inputs into a more creative, ambitious and effective result. Bold missions can provide new syntheses that are today impossible and thus will hopefully achieve the breakthroughs that are urgently needed to solve some of the most pressing issues facing our citizens.

1. MISSIONS FOR EU RESEARCH AND INNOVATION

Societal relevance

Research and innovation missions at the European level should be prioritised in those areas where the added value to the EU is greatest. A mission should have societal relevance, for example in the

ability to improve health, nutrition, or the living environment for a large section of European citizens across a range of Member States. Research and innovation missions should aim to improve society's welfare. This will require dedicated framing. For example, a mission on quantum computing could have strong societal impact if it is framed in terms of the potential to enhance cyber security, improve industrial processes, or support the development of new types of health care services. At the same time, the innovative spillovers that might result along the way may not be known beforehand and can have unforeseen applications. Indeed, most of the technologies in our smart products today — from the Internet to GPS — emerged as spillovers from missions of the past[92].

Nelson's work on The Moon and the Ghetto[93] asked the demanding question of why innovation has resulted in such difficult feats as landing a man on the moon, and yet continues to be so terribly disorganised and technologically unsavvy in dealing with the more earthly problems of poverty, illiteracy, and the emergence of ghettos and slums. He argued that while politics was partly the culprit, the real problem was that a purely scientific and technological solution could not solve such problems. There is a greater need to combine understandings of sociology, politics, economics and technology to solve these problems, as well as to make the conscious decision to point innovation towards them. This is exactly what a well-designed mission can achieve.

ENERGIEWENDE

There are lessons to be learned from how missions have been set at Member State level. The Energiewende in Germany addresses the important societal challenge of reducing carbon emissions, which are a key cause of climate change. The mission is framed with clear targets including that of exiting from nuclear power production in Germany by 2022.

While Energiewende contains a strong political steer, it is framed in such a way as to stimulate bottom-up research and innovation processes across multiple sectors, including, for example, sectors like steel that have otherwise remained relatively inertial. It was the Energiewende that stimulated steel to trial the conversion of smelting gas from steel production into base chemicals using renewable energy. Energiewende packages a complex mixture of policy, investment and legislation into one simple idea that makes it clear to German citizens that their government, scientists and businesses are working to make their society free of dependence on nuclear power. Energiewende is also interesting in that it addresses a concern that has arisen from decades of a citizen-driven green movement. This movement resulted in the societal legitimacy to set such a clear goal (the ambitions of the Energiewende are supported by 90% of the German population)[94]. Ultimately, Energiewende is based on a longstanding and growing sentiment of exiting nuclear power production but only became a mission after a political decision to engage based on the Fukushima nuclear disaster in Japan in March 2011 (we see a similar dynamic in how the Apollo mission responded to Sputnik). The lesson for European research and innovation missions is that they should be based on a selection process that starts with a political steer on topics of societal relevance, while simultaneously mobilising active public involvement in the decision-making on the choice for missions.

[92] Mazzucato, M. (2013) The Entrepreneurial State: debunking public vs. private sector myths, London: Anthem Press, UK

[93] Nelson, R.R. (2011) 'The Moon and the Ghetto Revisited', Science and Public Policy, 38(9), pp. 681–690. Available at: https://doi.org/10.1093/scipol/38.9.681 (Accessed: 12 February 2018)

[94] European Commission (2018) Mission-oriented R&I policies: Case Study Report Energiewende (DE). Available at: http://europa.eu/!md89DM

No 'one size fits all'

Missions come in different shapes and sizes. There is no 'one size fits all' definition of what a mission should be and how it should be structured. To allow research and innovation missions to create impact with societal relevance, flexibility is needed in how the mission is defined. In some areas, a mission should trigger action to speed up progress in the development of technologies to increase their societal impact. In other areas, the mission should drive a systemic change. Most likely, ambitious missions that have the potential to have wide societal impact will need a combination of both, but their characteristics may differ[95].

When developing a new mission, the art lies in learning from past missions, be it missions more focussed on diffusion or missions focussed on new frontier technologies, and adapting that knowledge and expertise to fit today's challenges and so defining and structuring a new mission. Putting 'old wine in new bottles' won't work[96]. We must allow missions to genuinely interact with the new types of complex problems societies face, as well as incorporating the new knowledge we have on how innovation comes about to their design: it is serendipitous, non-linear and very high risk.

Granularity: between a project and a challenge

Global challenges have been expressed as 17 Sustainable Development Goals (SDGs)[97]. One hundred and ninety three countries have signed up to these inspirational goals; hence, they provide an excellent opportunity to move forwards with mission-oriented thinking. They must be taken seriously as both an obligation to future generations and for global prosperity, but also as opportunities to steer investment led growth. Addressing these challenges, around health and the environment, must not be seen as a trade-off with a focus on economic growth. Rather they present a means to focus on opportunities for investment-led growth — crowding in activity across actors. In addition, targets must be set so that progression to achieving such challenges is as serious as the goal setting itself.

Within the European research and innovation context, Horizon 2020 introduced seven Societal Challenges to structure its programming. This process was complemented by Focus Areas, defining areas of activity that cut across several of the Societal Challenges, such as the circular economy, or digitisation. Even though this has led to a step-change in coherence and coordination, moving away from sectoral research and innovation programming, it has stopped short of delivering broad societal impact as impact is still assessed at the level of individual projects.

The SDGs, Societal Challenges or Focus Areas are useful to ensure focus, but for the most part remain too broad to be actionable. On the other end of the spectrum, research and innovation

[95] Foray, D., Mowery, D.C., and Nelson, R. R. (2012) 'Public R&D and social challenges: What lessons from mission R&D programs?', Research
Policy, 41(10), pp. 1697–1902.

[96] Mowery, D.C., Nelson, R. R. and Martin, B. (2010) 'Technology policy and global warming: Why new policy models are needed (or why
putting new wine in old bottles won't work)', Research Policy, 39(8), pp. 1011- 1023.

[97] European Commission (2018) The Sustainable Development Goals.
Available at: https://ec.europa.eu/europeaid/policies/sustainable-development-goals_en (Accessed 16 February 2018)

projects have clear objectives and are actionable, but will remain isolated in their impacts if not clearly linked to their ability to address global challenges and to achieve societal impact.

The 'granularity' of European research and innovation missions thus sits between broad challenges and concrete projects. Missions set clear and ambitious objectives that can only be achieved by a portfolio of research and innovation projects and supportive measures, such as policy interventions, deployment actions and involvement of end-users.

Missions should be broad enough to engage the public and attract cross-sectoral investment; and remain focussed enough to involve industry and achieve measurable success. By setting the direction for a solution, missions do not specify how to achieve success. Rather, they stimulate the development of a range of different solutions to achieve the objective. As such, a mission can make a significant and concrete contribution to meeting an SDG or Societal Challenge.

Figure 1 below illustrates the movement from broad challenges to specific missions.

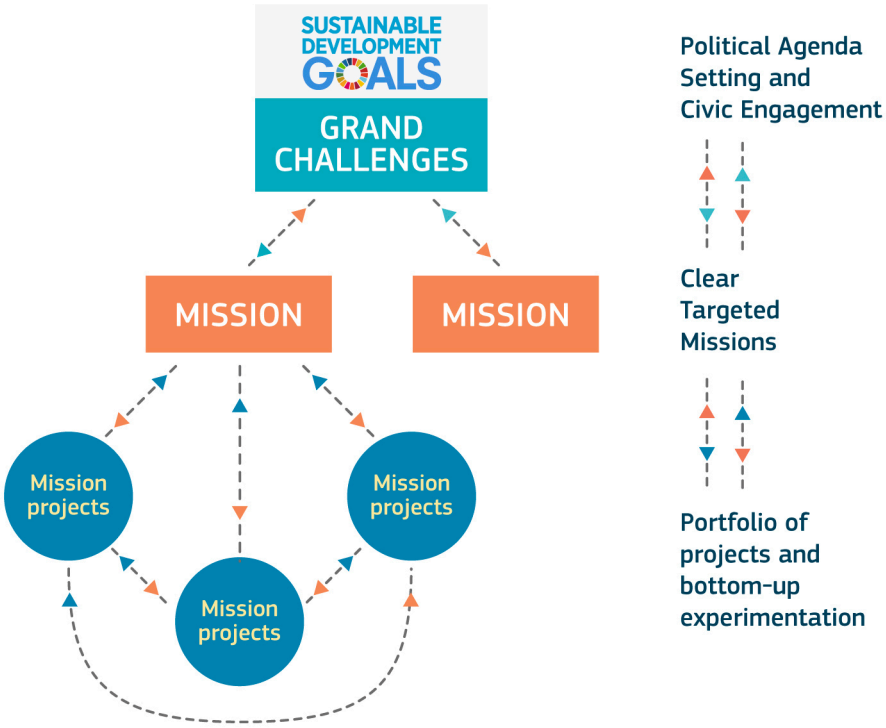


Figure 1. From Challenges to Missions Image: RTD - A.1 based on Mazzucato (2017)

For example, SDG 14 'Conserve and sustainably use the oceans, seas and marine resources for sustainable development' could be broken down into various missions, for example 'A plastic-free ocean'. This could stimulate research and innovation in means to clear plastic waste from oceans, or in reducing use of plastics, innovation in new materials, research on health impacts from micro-plastics, behavioural research and innovation to improve recycling or drive public engagement in cleaning up beaches. Each of these areas can be broken down into particular 'projects'. This is further analysed in the example section of this report, as well as other illustrative examples.

Fostering experimentation

Missions must be chosen. Yet their success will depend on the bottom-up processes that nurture innovation while 'getting there'. A culture of experimentation and risk-taking is a crucial element in the philosophy of missions. There must be incentives to 'think outside the box' to come up with new solutions to address the mission objective. This requires a portfolio approach, based on different solutions, and a broad range of different interactions. The objective should be addressed by multiple actors, stimulating cross-discipline academic work, with a strong focus on the intersection between natural sciences, formal sciences, social sciences and humanities; collaborations across different industries; and new forms of partnerships between the public sector, the private sector and civil society organisations. Innovation itself is often characterised by feedback effects, trial and error, and serendipity (the search for one thing leads to the discovery of another) - picking missions that have different possibilities for solutions will enhance the innovation dynamic itself.

New conversations between fundamental and applied research

Missions are not about prioritising applied research and innovation over basic fundamental research, which will continue to be funded by instruments like the European Research Council. Rather they are a new way to frame the conversations between the two, galvanising new forms of collaboration. Missions are also a new way to think about the dynamic interactions between enabling horizontal policies (framework policies around e.g. education, skills, training, research and innovation) and more directed vertical policies (e.g. health, environment, energy). Instead of using vertical policies to 'pick' sectors or technologies, the vertical aspect of missions picks the problem. The solution is then reached by stimulating multiple sectors and multiple forms of cross-actor collaborations to work to address those problems using the entire research and innovation value chain, from fundamental research to applied research and cutting-edge innovation.

FET Flagships

The EU has launched 'Future and Emerging Technology (FET) Flagships', initially on Graphene and the Human Brain, and more recently on Quantum. FET Flagships demonstrate a high level of ambition and commitment (€1 billion from a range of sources over a number of years) with a strong technology-driven approach based on multidisciplinary research activities.

Their high ambition and significant public EU research investment have crowded-in industry partners and mobilised private investment. Based on these characteristics, FET Flagships show a high degree of alignment with EU research and innovation missions as described in this report.

However, the FET Flagships have not so far put the same emphasis on public engagement or on defining goals and milestones in terms of societal relevance, even though they do aim to turn scientific and technological developments into innovations that can be brought to market, and aim to support societal challenges. The experience from the current FET flagships should prove valuable for designing and implementing future missions, and applying the selection criteria, implementation requirements and public engagement criterion proposed here could increase the impact and visibility of FET flagships as future missions.

2. FIVE KEY CRITERIA FOR SELECTING MISSIONS

Selecting missions that matter to society and stimulate innovation across multiple sectors is a highly complex task. Missions come in different shapes and sizes, but the European research and innovation missions should fulfil the following key criteria.

(1) Bold, inspirational with wide societal relevance

Missions should engage the public. They should make clear that through ambitious, bold action at the European level, solutions will be developed that will have an impact on people's daily lives. To do this, missions must outline exciting opportunities for bold innovation — while being connected to debates in society about what the key challenges are, like sustainability, inequality, health, climate change, and increasing the quality of the welfare state. Therefore, a mission cannot only have relevance for the population of one Member State, or a small sub-set of the European population. It should touch the lives of, or inspire, a significant part of the European population. However, it is important to note that relevance does not necessarily equate with popularity.

(2) A clear direction: targeted, measureable and time-bound

Missions need to be very clearly framed. While enabling long-term investments, they need a specific target that can either be formulated in binary ways (as clearly as whether man has reached the moon and returned back safely) or quantified (as clearly as whether a certain percentage reduction in carbon emissions against a baseline has been reached across manufacturing). In addition, they will need a clear timeframe within which actions should take place. This needs to be long enough to allow the process to grow, for actors to build relationships and interact, while at the same time being time-limited. Without specific targets and timing, it will not be possible to determine success (or failure), or measure progress towards success.

(3) Ambitious but realistic research & innovation actions

Mission objectives should be set in an ambitious manner (taking risks), centred on research and innovation activities across the entire innovation chain, including the feedback effects between basic and applied research. Ambitious objectives will ensure that researchers and innovators are challenged to deliver what would otherwise not be attempted ("additionality" in research). Yet, the objective should be framed to be on the one hand high-risk but also realistically feasible, at least in theory, within the given time period. Setting the technical objectives unrealistically high will result in a lack of buy-in, while setting the objective too low will not incentivise extra efforts – or provide inspiration. Furthermore, the required technological development should attract research and innovation activities that otherwise would likely not be undertaken by private actors, providing the justification and legitimacy for public intervention. This does not have to be done within a narrow market failure framework, but a more active market 'co-creation' framework[98].

(4) Cross-disciplinary, cross-sectoral and cross-actor innovation

Missions should be framed in such a way as to spark activity across, and among, multiple scientific disciplines (including social sciences and humanities), across different industrial sectors (e.g. transport, nutrition, health, services), and different types of actors (public, private, third sector, civil society organisations). Missions need to be chosen to address clear challenges that stimulate the private sector to invest where it would not have otherwise invested ("additionality" in business). By

[98] Mazzucato, M. (2016) «From Market Fixing to Market-Creating: A new framework for innovation policy», Special Issue of Industry and
Innovation: "Innovation Policy – can it make a difference?", 23 (2)

taking a problem focussed lens and not a sectoral lens, problems related to sustainability will not just involve, for example, renewable energy, but could also involve transport, strategic design, new digital solutions, amongst others. Similarly, problems related to health will not only involve innovation in pharmaceuticals but also in such areas as nutrition, artificial intelligence, mobility and new forms of digitally enhanced public service provision.

Missions connect all relevant actors through new forms of partnerships for co-design and co-creation by focussing on targets that require multiple sectors and actors to solve. Thus, mission-oriented innovation has the possibility of leading to system-wide transformation.

(5) Multiple, bottom-up solutions

Missions should not be achievable by a single development path, or by a single technology. They must be open to being addressed by different types of solutions. A mission-based approach is clear on the expected outcome. However, the trajectory to reach the outcome must be based on a bottom-up approach of multiple solutions — of which some will fail or have to be adjusted along the way.

3. IMPLEMENTATION

The mission concept and proposed criteria provide a basis for identifying EU level research and innovation missions. However, the future missions will also require new approaches to implementation. They should not be managed in the same way as other parts of the Framework Programme, like the European Research Council or future European Innovation Council (which are bottom up), or the current approach to the Societal Challenges. While lessons must be learned from the latter due to the importance of challenges in setting the direction for change, missions are more concrete than challenges and thus for their implementation we must also learn from successful mission-orientated organisations around the world — of course adapted to the EU context.

The main lessons can be grouped under the following aspects

Engagement of diverse national and regional stakeholders

Mission objectives should provide legitimacy, such as relevance to the SDGs, EU priorities and/or Member State priorities; the mission should not exist in a vacuum. While EU investments in research and innovation are a basic condition, a broader political commitment to align policy objectives at both the EU and Member State level will be critical to implement a successful mission.

Missions should engage as much as possible with Member State strategies, including industrial strategies - which in many countries have made a comeback. Indeed a mission-based approach is a useful lens for an industrial strategy to be based around, so that it is not about picking sectors or technologies but about picking problems to guide innovation across multiple actors in multiple sectors[99]. This will lead to more complementary public investments from European, national or regional programmes, and also additional private investments, creating a catalysing effect on the

[99] For example, the UK Government's recent Industrial Strategy White Paper states that the strategy will be focussed on addressing 4 key
societal challenges: Clean Growth, Future of Mobility, AI and the Data Economy, and the Ageing Society. Helping to translate these
challenges into multiple missions is the task of the new UCL Commission for Mission Oriented Innovation and Industrial Strategy (MOIIS).

chances for success. Hence, missions can serve as a way to initiate new EU-wide and national dialogue around the role of public sector support for research and innovation – not only fixing market failures but also more actively co-creating and co-shaping new markets.

Selection of a mission that will incite broad public engagement, as well as a wide interest from industry and civil society stakeholders, can spur further political commitment. Crucial to the implementation of EU missions will be the need to reinvigorate capacity building in public organisations and institutions as well as competencies and expertise at European, Member State, regional and local level. This is essential to effectively coordinate and provide direction to participants when formulating and implementing missions

Measurement and impact by goals and milestones

It is essential for missions to define a concrete target and objectives. That is to say, it must be possible to say definitively whether the mission has been achieved or not. Appropriate indicators and monitoring frameworks will need to be established to measure progress. They must be dynamic, recognising that static cost-benefit analysis and net present value calculations would most likely stop any bold mission from the outset.

While missions must allow for long-term investments, the use of intermediate milestones is critical. Intermediate milestones will provide the means to keep track of progress towards the mission objective and allow for informed and flexible adaptive decisions to intervene. Real-time data, publicly available, on progress on the milestones will also keep a sense of urgency, achievement and motivation among involved actors. The use of AI and big data for creating dynamic metrics will be very important.

Intermediate milestones will also be important for flexibility and adaptation so that the mission can be changed over time if the milestones provide new information or show that the mission, for whatever reason, has been framed problematically and needs adjusting. While missions are long-term and should have a stable goal, the intermediate signposts should be used to decide whether changes in direction are required, and, in some cases, whether the mission itself needs redefining.

In addition to the milestones, broader measures of the cross-sectoral and cross-science impact are needed. So even if a milestone or the overall mission objective is not reached, the mission might still be considered to be successful (at least to an extent) if the process produced positive, economy-wide spillovers (e.g. the Internet was not discovered because of an ex-ante objective, but rather as a solution to a problem that scientists had in the late 1960s around allowing multiple computers to communicate on a single network.). Indeed, creating cross-sectoral spillovers can be an objective itself, best achieved when the process of innovation remains open and cross-disciplinary.

A portfolio of instruments to foster bottom up solutions

A mission is not a single project, but a portfolio of actions that can encourage multiple solutions. A diverse set of different funding instruments will help achieve this, from grants, to prizes, to new forms of procurement, and financial instruments. This will guarantee that public funding is allocated to a diverse set of activities with a focus on complementarities, and avoiding duplication. The process should explicitly be one that admits the tension between the top-down direction setting and the bottom-up explorative approaches. Rather than prescriptive specifications of projects, participants should be given flexibility to propose a variety of solutions for achieving the mission goals and intermediate milestones. This will nurture bottom-up experimentation, but in each case the lessons (and data) from the experiments should be collected, analysed and understood.

This would mark an important change from programme management and evaluation under Horizon 2020. Rather than managing projects in isolation and according to project specific objectives, a portfolio of projects would be managed to stimulate interaction, experimentation and cross-learning. Rather than evaluating at the level of the overall programme following the completion of actions, evaluation would be an integral part of the mission and feed into the ongoing implementation and management of projects and funding. This would also avoid funding projects that simply support existing networks without necessarily adding new value.

Flexibility, pro-active management and building in-house capabilities

Missions are a concerted effort to reach a pre-defined objective through a multitude of actions. As the focus is on reaching an outcome, a high degree of flexibility and adaptability is required to allow the possibility to change course if there is a risk that the objective will not be achieved.

In budgetary terms, there should be a possibility to increase the budget for a mission if there are indications that extra investment (within boundaries) could make the difference between reaching a mission objective or not. Similarly, if indicators consistently point towards a situation where a mission objective is out of reach, the possibility to terminate a mission should also be conceivable.

Such decisions should be based on metrics that can orchestrate the (tricky) balance between the need for some form of ex-ante dynamic risk assessment and the danger of writing off potentially viable missions at an early stage because ex-ante impact assessments cannot predict the kind of unexpected spillovers the mission approach can cause.

This has implications for how European public research and innovation funding is allocated and assessed. Evaluation of project proposals should pay as much attention to the portfolio of projects, as to the excellence of individual proposals. If individual projects, after a period of time and based on clear indicators, seem not to be contributing to the mission objective, it should be possible to redirect funding to other activities. In a similar vein, to ensure the maximum contribution of activities to the mission objective, funding should be distributed on a 'stage-gate' principle, where successive tranches of funding are only allocated based on reaching an intermediate milestone.

This proactive approach to the management of a portfolio of projects requires significant in-house capacities and expertise. Lessons should be learned from mission-oriented organisations like DARPA and ARPA-E in the US, Yozma in Israel, SITRA in Finland and Vinnova in Sweden. The point is not to copy these organisations but to learn from key sources of their success. For example, these organisations have explicitly welcomed risk-taking at the organisational level; they have used secondment practices to bring high-level scientists into the civil service for limited time periods; they have often aligned goals with national procurement practices; and have been extremely good at drawing on expertise of wider networks[100]. Such organisations develop what has been called

[100] The Institute for Innovation and Public Purpose (IIPP) at University College London has launched a Mission Oriented Innovation Network
(MOIN) that creates a platform where lessons are learned between global mission-oriented agencies, with particular emphasis on
the way in which ambitious organisational goals are created, internal capabilities nurtured, and dynamic metrics used to capture the
market shaping effect of mission oriented policies.
Available at: https://www.ucl.ac.uk/bartlett/public-purpose/partnerships (Accessed 16 February 2018)

'mission mystique'[101] or institutional charisma: It is an honour to work in a mission-oriented organisation where ambitions for the use of innovation to solve problems are as important as building in-house capacity and expertise.

Unfortunately, the trend is for much of the in-house knowledge to be outsourced to third parties, whether consulting companies, think tanks or the private sector. This is particularly noticeable in policy and programme evaluations where increasing number of public organisations rely on external evaluators. While some outsourcing is fine (scientific peer-review is a case of outsourcing), it is also crucial to build dynamic capabilities inside public institutions that are responsible for engaging with technological and scientific priorities. While public organisations may require more long-term stability than private ones, they still must nurture risk-taking and experimentation– and hence such capabilities have to be consciously nurtured in the public sector.

This means we have to be willing to rethink the curricula for public administration (including the relevant executive education programmes) as well as key quality and performance management tools and metrics widely employed in public organisations. Public institutions in charge of mission-oriented policies need to be willing to experiment with both bringing in new expertise (e.g. establishing novel forms of collaboration with third-sector organisations to pool and share expert knowledge[102]) and changing everyday routines and processes to build dynamic organisational capabilities (including dynamic performance management, procurement, and human resources).

4. PUBLIC ENGAGEMENT

The issue of public engagement and missions is crucial because of the symbiotic nature of the relationship between the two. Missions provide a straightforward explanation to the public of how diverse, and sometimes difficult to understand, developments in research and innovation contribute to a better society. In addition, the potential impact of missions is much higher when they inspire and engage widespread support.

Missions must be framed within challenges that are broadly agreed to be of high societal importance. This will ensure their longevity and survival across political cycles as well as contributing to their success. It will ensure that citizens can clearly see the benefits that European research and innovation in particular, and EU intervention in general, bring to their lives and communities. In order to capture this, meaningful public participation in the selection process of missions is a prerequisite.

Therefore, even though the nature of missions requires that they be selected at the political level, the selection process must have a strong element of public involvement. This is both because innovation benefits from multiple and diverse influences, and also because without civic engagement, the risk of alienation from the broader public and a purely technocratic approach is too high. A mission will not inspire people unless they are part of it. A rigorous process of evaluation is

[101] Goodsell, Ch. T. (2011) 'Mission Mystique: Strength at the Institutional Center', *The American Review of Public Administration*, 41(5), pp.
475–494.

[102] An excellent example of how to bring expertise into public organisations is Public Practice in the UK, which seeks to bring back the expertise of
high level planners and architects into the innovation-led strategies of city level governments. See:
http://www.publicpractice.org.uk (Accessed 1
February 2018)

needed to ensure continuing relevance and commitment and to prevent selection being captured by either passing fashion or vested interests.

Public participation in the selection process must be followed by public inclusion in the implementation. Keeping society informed of progress and achievement of intermediate milestones, for example using social media or community based workshops, could play a role in maintaining broad interest and thus incentivising continuation of the mission. The opportunities for such engagement will of course differ depending on the nature of the mission, but some form of genuine participation of civil society organisations in concrete projects within a mission will be crucial to facilitate open dialogues on expected outcomes and practical applicability of solutions. Furthermore, as missions are cross-actor and cross-discipline, social innovation will be a key element of implementation. Citizens can possibly be mobilised to become active participants in missions, for example by cleaning plastics from beaches or by providing real-time monitoring data as enabling technologies develop and become more universally present in society.

Furthermore, innovation often finds its true purpose in the hands of consumers who work out what a technological innovation is really capable of or what it can be used for. Innovation is still born until people find a way to fit it into their lives. So while it is important that missions pervade the supply side of innovation (driving communities of knowledge to bring about important changes), innovation can also come from the demand side (people discovering what a technology is for in the process of using it, or solving important problems they face). Indeed, there is lots of evidence from within innovation processes that this interaction between supply side and demand side is vital to the success of missions[103].

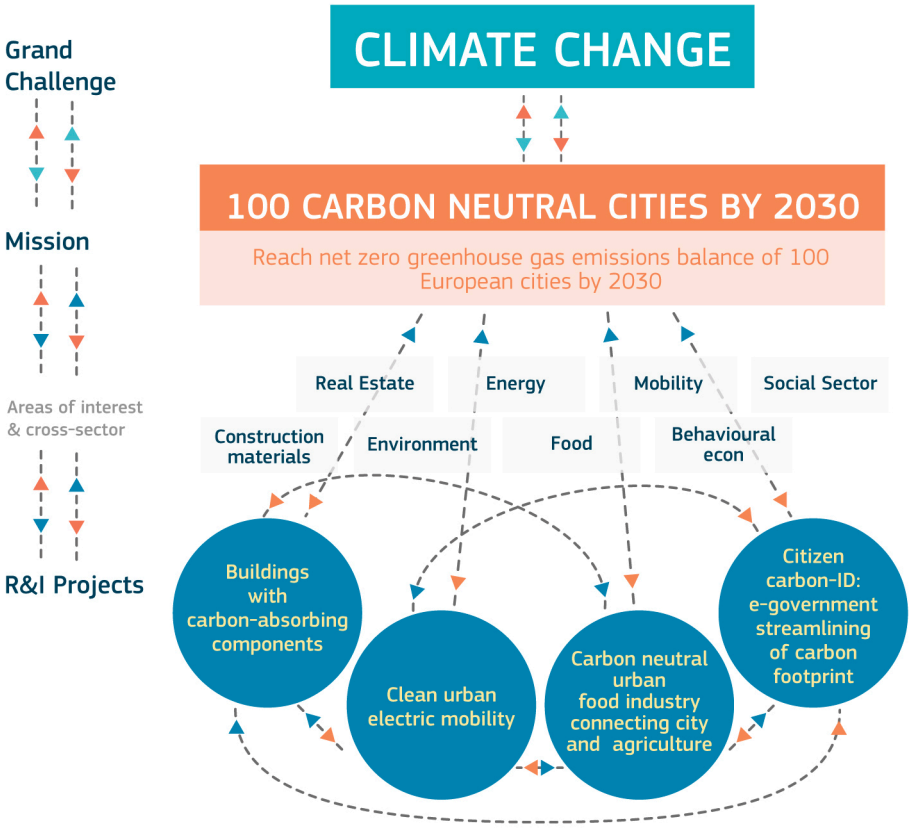
All available and proven channels of communication with citizens should be explored so citizens can feel enthusiasm and trust in the process of change. The precise constellations of civil society, public and private actors that should be involved will only be fully developed when particular missions are selected.

5. EXAMPLE MISSIONS OF THE FUTURE

This report is not designed to decide what the future European research and innovation missions should be, but rather to offer guidance in their selection and implementation. It is useful, nonetheless, to provide some examples of how to define missions, based on the criteria described in this report. The three examples below are solely for pedagogical use. They are not, and nor are they intended to be, scientifically, technically, or otherwise complete. For each of the three examples, the five criteria for mission-setting, as described above, are exemplified and illustrated.

100 Carbon Neutral Cities by 2030

[103] For ideas on how the web can be used to increase demand side participation, see Leadbeater, C. (2009), We-Think, UK: Profile Books



(1) Bold, inspirational with wide societal relevance

By 2030, 80% of European citizens will live in cities. European values, culture and productivity are closely related to cities. Cities are important drivers of innovation; they have close interactions with citizens and have the ability to test solutions at scale. By turning 100 cities across Europe into fully carbon-neutral places to live and work, about 40% of European urban citizens could benefit from cleaner air and Europe would take a major step forward in achieving the objectives of the Paris Climate Agreement.

(2) A clear direction: targeted, measureable and time-bound

One hundred cities reaching a net zero greenhouse-gas-emission balance by 2030 is a concrete target that can be definitively measured. Different timelines and intermediate milestones can be used for cities of different size or economic basis.

(3) Ambitious but realistic research & innovation actions

Research and innovation activities across the entire innovation chain are essential to reach a carbon-neutral balance for cities. Collaboration and feedback loops between basic research (such as the carbon-absorption capacity of construction materials), applied research (such as sustainable urban mobility and freight options), and social, entrepreneurial innovation (such as incorporating citizen carbon-ID in the real estate market and daily purchases), will be essential. Such knowledge-based research and innovation could work in conjunction with regulatory and governance actions to see that the mission target is reached.

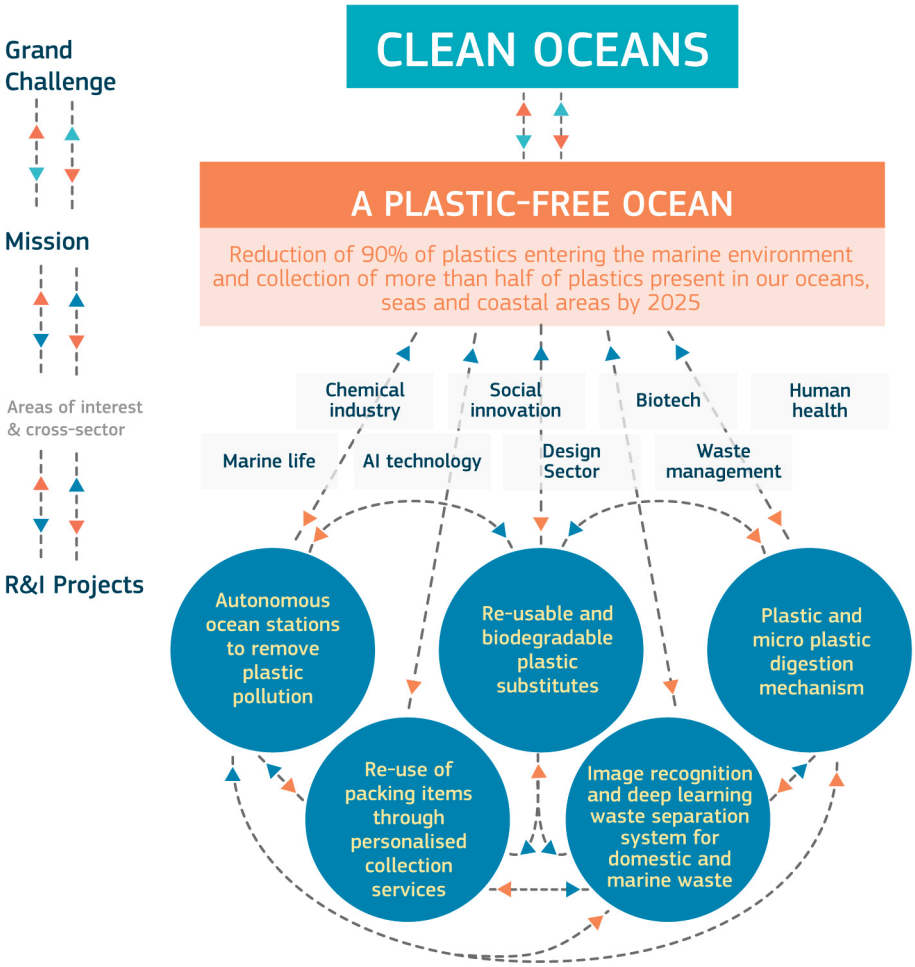
(4) Cross-disciplinary, cross-sector and cross–actor innovation

Cities play an important yet different role in the life of all actors of society and therefore need the involvement of engineers, social workers, planners, environmental scientists, data analysts, economists, citizens, policy makers and other actors. To achieve carbon neutrality in cities, these actors need to collaborate across sectors, such as urban planning, construction, energy efficiency in buildings, mobility, behavioural aspects, food, environmental capacity etc. while incorporating cross-disciplinary research such as urban planning, energy efficiency in buildings, mobility, consumer behaviour and innovative business.

(5) Multiple, bottom-up solutions

Carbon neutrality in cities can only be reached through a systemic approach including all the different activities and functions of urban areas. This requires a multitude of research and innovation projects, combined with policy, governance and civil engagement, that may have specific objectives (such as facilitating domestic use of renewable energy, incentivising electro-mobility or developing materials for energy efficient building, etc.), but that need to be aligned and interact with one another to multiply the overall impact.

A plastic-free ocean



(1) Bold, inspirational with wide societal relevance

Every year, Europeans generate 25 million tonnes of plastic waste, of which less than 30% is recycled. Plastic makes up 85% of beach litter. There are two strands to tackling plastic ocean pollution. First existing plastic pollution must be removed from the ocean and second, new ways must be found to curtail the entry of new plastic waste to the oceans. Drastically reducing the amount of plastic that enters and floats in the oceans will have a substantial impact on the health of European citizens, marine life and the environment. This mission would be closely aligned with the objectives of the recently adopted Plastics Strategy[104] creating an important interaction between research and innovation activities and policy development.

(2) A clear direction: targeted, measureable and time-bound

This mission could have a clear target to reduce the amount of plastic entering the marine environment by 90%; and of collecting more than half of the plastic currently present in our oceans, seas and coastal areas. This would mean stopping at least 7.2 million tonnes of plastic entering the marine environment and collecting at least 2 million tonnes of plastic per annum from oceans, seas

[104] European Commission (2018) European Strategy for Plastics. Available at: http://ec.europa.eu/environment/waste/plastic_waste.htm (Accessed 16 February 2018)

and coastal areas. A very ambitious, yet achievable timeline to reach this target would be circa 5-10 years.

(3) Ambitious but realistic research & innovation actions

Research and innovation activities across the entire innovation chain would be essential to reach a plastic-free ocean. Research actions would also need to target the reduction of impact of marine litter on human and animal health. Collaboration and feedback loops between basic research (such as chemical research on characteristics of plastic), applied research (such as biotech applications in packaging design) and entrepreneurial innovation (such as on-sea plastic collection stations) will be essential. Such knowledge-based research and innovation could work in conjunction with regulatory and governance actions to see that the mission target is reached.

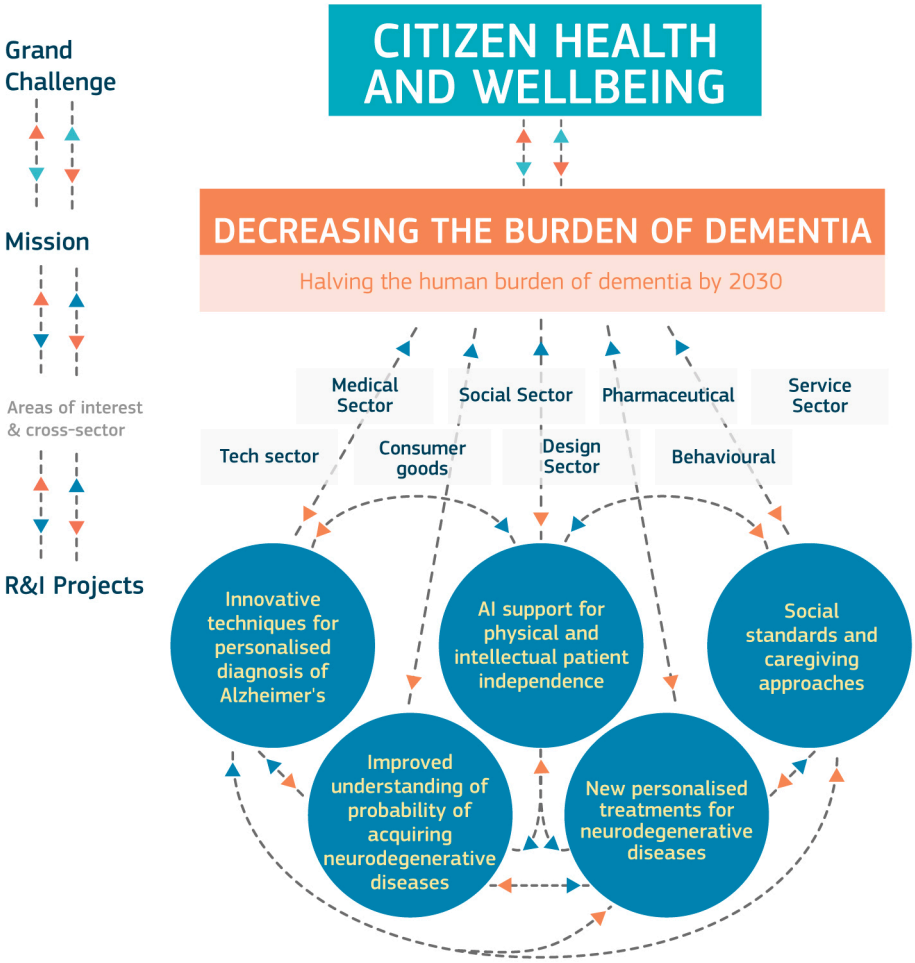
(4) Cross-disciplinary, cross-sectoral and cross-actor innovation

Oceans are a source of life for society. Many different actors of society will need to be involved (such as chemical engineers, marine biologists, marketing experts, environmental scientists, earth observation specialists, fishermen, citizens at large, etc.). These different actors will need to collaborate across sectors such as chemical, biotech, marine life, consumer goods, Artificial Intelligence, health, design, waste — while incorporating cross-disciplinary research such as product design, in particular design for the food processing chain (packaging of food), cosmetics, tyres and textiles.

(5) Multiple, bottom-up solutions

Removing plastics from the ocean is such a large and complex exercise, that it could not be achieved by a single technological (or policy) solution. It will require a combination of various solutions, focusing on different facets of the problem, which will need to be coordinated in order to reinforce each other. Interaction between projects, and experimentation and risk-taking, can increase additionality. For example, an autonomous ocean plastics management station might take time to implement, but the knowledge base for this station could be used to inform a hybrid, plastics-digestion mechanism, which could be implemented first, possibly in the form of distributed nets. This might kick-start an innovative and more efficient way of overall ocean plastics removal.

Decreasing the burden of dementia



(1) Bold, inspirational with wide societal relevance

European values are closely connected to a high quality of life, optimising care and wellbeing and balancing family life and work. Dementia is a syndrome that currently afflicts 10.5 million Europeans (expected to rise to 18.7 million people by 2050). Halving the human burden of dementia would both mean a tremendous impact in terms of improvement of quality of life for patients and families of patients with dementia. On top of the human cost dementia is estimated to currently cost around €530 per citizen per year.

(2) A clear direction: targeted, measureable and time-bound

The target is to halve the human burden, by reducing by 50% the progression of the disease in affected patients. A very ambitious yet feasible timeline for this target is 10 years. This would represent a saving of €92 billion in anticipated healthcare over that 10-year period (or around €9 billion per year). To track whether the target has been reached, intermediate milestones like the number of patients presenting an earlier clinical status of dementia and the average age at which dementia is diagnosed could be defined.

(3) Ambitious but realistic research & innovation actions

To reduce the progression of dementia in patients research and innovation activities across the entire innovation chain would be essential. Collaboration and feedback loops between basic research (such as brain-science on neurodegenerative diseases), applied research (such as personalised treatments of dementia) and entrepreneurial innovation (such as artificial intelligence for patient independence), will be essential. Such knowledge-based research and innovation could work in conjunction with regulatory and governance actions to see that the mission target is reached.

(4) Cross-disciplinary, cross-sector and cross–actor innovation

Dementia is a syndrome that affects many parts of society. It can only be addressed by bringing together a wide range of actors, such as patients, doctors, social workers, families, designers, teachers, programmers, laboratory workers. These actors will need to collaborate across sectors, (such as medical, tech, social, consumer goods, pharmaceutical, design, service sector, behavioural economics, etc.), while incorporating cross-disciplinary research (such as integrated digital technologies (e.g. big data, e-health records, sensors, mobile devices, and telemedicine) for better monitoring and independent living interactions between artificial intelligence, behavioural sciences and molecular biology for early detection of dementia).

(5) Promote multiple, bottom-up solutions

The pervasiveness of dementia in society means that addressing this challenge can only be achieved by tackling a wide variety of elements that can each contribute to the mission. There is not a single avenue to solve the problem. For example, innovative early-diagnosis tools and techniques might take more time to develop and need more inputs from basic research before implementation in applied research. Nevertheless, linking the knowledge of one project with other parallel projects on e.g. awareness and training, could help to develop knowledge and ability to implement behavioural changes in social standards and caregiving.

6. CONCLUSION

Europe has major strengths, not least among them our research and innovation system, built on many successive years of investment by Member States and the Union alike. But Europe is at a crossroads and faces many major challenges — from inequality to rising air pollution to antiquated health systems. Rather than let the challenges overwhelm us and feed rising populism we have an opportunity, as we stand on the cusp of the 9th European Framework Programme for Research and Innovation, to turn these challenges into opportunities for change, for new forms of interactions, and for revived innovation-led growth.

The key insight of this report is that missions are both a means of setting economic growth in the direction of where we want to be as a society and a vehicle we can use to get there.

I have outlined the key criteria to help European policy makers choose missions that will be ambitious, engaging and achievable. I have outlined the main broad issues around implementation to guide the policy makers as they put a formal shape on missions in the coming years and I have outlined examples of what European level missions could look like. It will take a lot of work by many people and organisations but, if Europe can get mission-oriented policy right, the potential benefits are staggering. This is not about low-tech and high-tech but about getting the entire economy,

across EU Member States working towards achieving goals that were implied but not actioned enough in Horizon 2020.

On the occasion of a conference I organised in 2014 on Mission-Oriented Finance for Innovation[105], I asked Cheryl Martin, the Director of the US innovation agency in the Department of Energy, ARPA-E what she considered the driving factors in the success of her agency which has been responsible for some of the most advanced innovations on battery storage. She said that the key was to measure success firstly by how much risk they were willing to take and secondly by how much impact the successes had across society. There is much to learn from the balance and portfolio thinking implied by this approach: take risks but make sure successes really matter!

I hope this report will serve as a stimulus for Europe to gain courage to take the risks needed to launch a new vision of a problem-solving approach to innovation-led growth — that matters. A vision that will involve multitudes of EU stakeholders and be bold enough to awaken passion in science, technology and the humanities by reframing challenges and solutions in such a way that the process is just as exciting as the outcome.

[105] Mazzucato, M. and Penna, C. (eds.) (2015) Mission-Oriented Finance for Innovation: New Ideas for Investment-Led Growth, Rowman & Littlefield. Available at: http://www.policy-network.net/publications/4860/Mission-Oriented-Finance-for-Innovation (Accessed: 12 February 2018)