A framework for mission-oriented innovation policy roadmapping for the SDGs:

The case of plastic-free oceans

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A framework for mission-oriented innovation policy roadmapping for the SDGs:

The case of plastic free oceans

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Abstract

Governments and international organisations have recognised the potential of science, technology and innovation (STI) to enable and accelerate the transition towards the Sustainable Development Goals (SDGs). There is a need to re-align and streamline public policies and investments to harness the benefits of STI for the SDGs more effectively.

This paper proposes a mission-oriented innovation policy roadmapping framework as a systemic policy instrument – or a strategic framework for action – to give a long-term orientation to innovation support. The paper argues policy roadmaps have a potential to improve the coherence of innovation policies, and to create synergies between public, private and civil society initiatives and investments in high-impact mission-oriented innovations for the SDGs

The paper proposes an architecture and step-wise process for designing and implementing mission-oriented innovation policy roadmaps. The approach adapts the roadmapping technique to innovation policy making instrument portfolios and governance mechanisms. The paper includes an illustrative case study applying the analytical steps of the framework to 'A Plastic-free Ocean' mission.

Keywords: innovation policy; mission-oriented policy; policy roadmapping; SDGs; plastic free-ocean

JEL codes: L52, O14, O21, O25, O30, O38, Q01, Q55, Q58

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Introduction

This paper proposes and tests a mission-oriented policy roadmapping framework and process to help governments and international organisations address long-term societal challenges by supporting selected high-impact missions.

The mission-oriented approach to science, technology and innovation (STI) roadmapping is proposed to champion a problem-based approach to innovation policy (Mazzucato, 2018a; Mazzucato, 2018b). We argue policy roadmaps have the potential to provide long-term orientation and ensure the coherence of innovation policy, while opening up spaces for continuous learning and experimentation. We consider policy roadmaps good candidates to become systemic policy instruments (Smits and Kuhlmann, 2004; Wieczorek and Hekkert, 2012; Kattel et al. 2018), which can guide innovation policy mixes to accomplish missions and contribute to the Sustainable Development Goals (SDGs).

The paper develops a conceptual framework and step-wise approach to designing and implementing mission-oriented innovation policy roadmaps for societal challenges and the SDGs. This framework should be seen in the context of the ongoing international debates on how to mobilise STI to address the SDGs and major societal challenges. The 2030 Agenda placed STI among the key means of accomplishing the SDGs and launched the UN Technology Facilitation Mechanism (TFM) to focus on the role of innovation in meeting the goals. STI roadmaps and action plans have been among the key topics discussed in the context of the TFM, notably at the annual UN Fora for STI and at the expert meetings of the Inter-Agency Task Team on Science, Technology and Innovation for the SDGs (IATT). These debates confirm the need for innovative approaches to STI policy that harness research and innovation for the SDGs. These new frameworks and instruments need to create deliberative spaces for government and stakeholders to co-create shared visions and mission objectives, while drawing on best available knowledge and expertise.

This document prepares the ground for pilot applications of the framework. Section 1 provides a brief introduction to the concept of mission-driven policy. Section 2 introduces our understanding of innovation. Section 3 reflects on the challenges of mission-driven policy for STI policy mix and policy portfolios. Section 4 introduces roadmaps as a potential instrument for planning and coordinating mission-oriented innovation policies, and proposes a new framework for mission-oriented innovation policy roadmapping for the SDGs. Section 5 introduces a step-wise process to design and implement the proposed framework. Section 6 provides a tentative illustration of the application of the framework to ‘A Plastic-free Ocean’ mission. The final section summarises key findings and messages.

1. What are mission-oriented policies?

Mission-oriented policies can be defined as systemic public policies that draw on frontier knowledge to attain specific goals – in other words 'big science deployed to meet big problems' (Mazzucato, 2018a; 2018b). 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 people across the globe.

It is increasingly recognised by policy makers that these kinds of grand challenges – the transition to a low-carbon energy system, refashioning the welfare state to deal with an ageing population or creating affordable homes in the world's fast-expanding major cities – cannot be dealt with simply via market solutions. These challenges cannot be reduced to 'externalities' or 'public goods'. They are more like complex design problems that require radical innovations and multiple areas of the economy to alter their trajectory. In fact, they mandate a different approach to economic growth. Policy makers today are seeking smart, inclusive and sustainable growth – in other words they are recognising that economic growth has a rate but also a direction. To create a new direction – such as green energy – requires the creation and shaping of new markets, not just correcting existing market failures. Such change requires new efforts by both private and public actors, as well as an important role for civil society. The role of the state is key here since it is the only institution with the power to shape markets and direct economic activity in socially desirable directions to achieve publicly accepted outcomes (Mazzucato 2013, 2016). In this context, industrial and innovation strategies become key pillars to achieve transformational societal change – in particular, by identifying and articulating new *missions* that can galvanise production, distribution and consumption patterns across various sectors (Mazzucato 2018a, 2018b).

The market-shaping, mission-oriented approach to policy cuts through the problematic state-market dichotomy that dominates much discussion on economic efficiency and value, with its origin in market failure theory and its critique. Under this approach, the market and the economy itself are viewed as an outcome of the interactions of individuals, firms and the state over time, following Karl Polanyi's (1957) notion of the 'embeddedness' of the economy in society and culture. 'Mission-oriented public policy' is not about removing market imperfections or 'levelling the playing field' to ensure greater competition, but about 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 (e.g. energy storage), the type of finance that is needed (Mazzucato and Semieniuk, 2017; Semieniuk and Mazzucato, 2018), the types of innovative firms that will need extra support, the types of collaborations with other actors to be pursued (in the third and private sectors), and the types of regulations and taxes that can reward the behaviour that is desired.

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 period of time. They require different sectors to come together in new ways: climate change cannot be fought by the power sector alone, it will 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 and value chains (UCL Commission on Mission-Oriented Innovation and Industrial Strategy, 2019).

As an example, the Apollo mission to the moon required innovation across many different high-tech sectors (e.g. aerospace) and low-tech sectors (e.g. 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. Furthermore, while the Apollo mission was purely technological, modern problems are more complex and 'wicked' requiring the need to bring together technological, social/behavioural, organisational and political changes. It is this complexity of societal challenges that made Richard Nelson compare the challenge of going to the moon with the harder challenge of solving inequality and the "ghetto" (Nelson, 2011).

The public sector has historically also been important for the direct creation of markets through procurement policy (Edler and Georghiou, 2007) and for bold demand policies that have allowed new technologies to diffuse. Thus, Perez (2013) argues that 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. 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 SDGs or societal challenges.

The idea is to start off with a broad challenge that would for the most part be stimulated by the SDGs. This should then be turned into concrete targeted problems that can require multiple sectors to invest, multiple actors to collaborate (private, public, third sector and civil society) and many 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? How can public policy support for transformative innovation create favourable systemic conditions for innovators? What are instruments to ensure directionality and effectiveness of public intervention?

The logic underlying this process can be seen in the diagram below (Figure 1) and applied to clean oceans (Figure 2). SDG 14: 'Conserve and sustainably use the oceans, seas and marine resources for sustainable development,' for example, could be broken down into various missions, such as 'A Plastic-free Ocean'. This could stimulate research and innovation in the means to remove plastic waste from oceans, to reduce use of plastics and encourage innovation in materials or to improve recycling, as well as to drive public engagement by cleaning up beaches or changing consumption patterns by avoiding single-use plastics. Each of these areas can be broken down into specific 'innovation projects'.

Figure 1. From broad societal challenges to mission projects

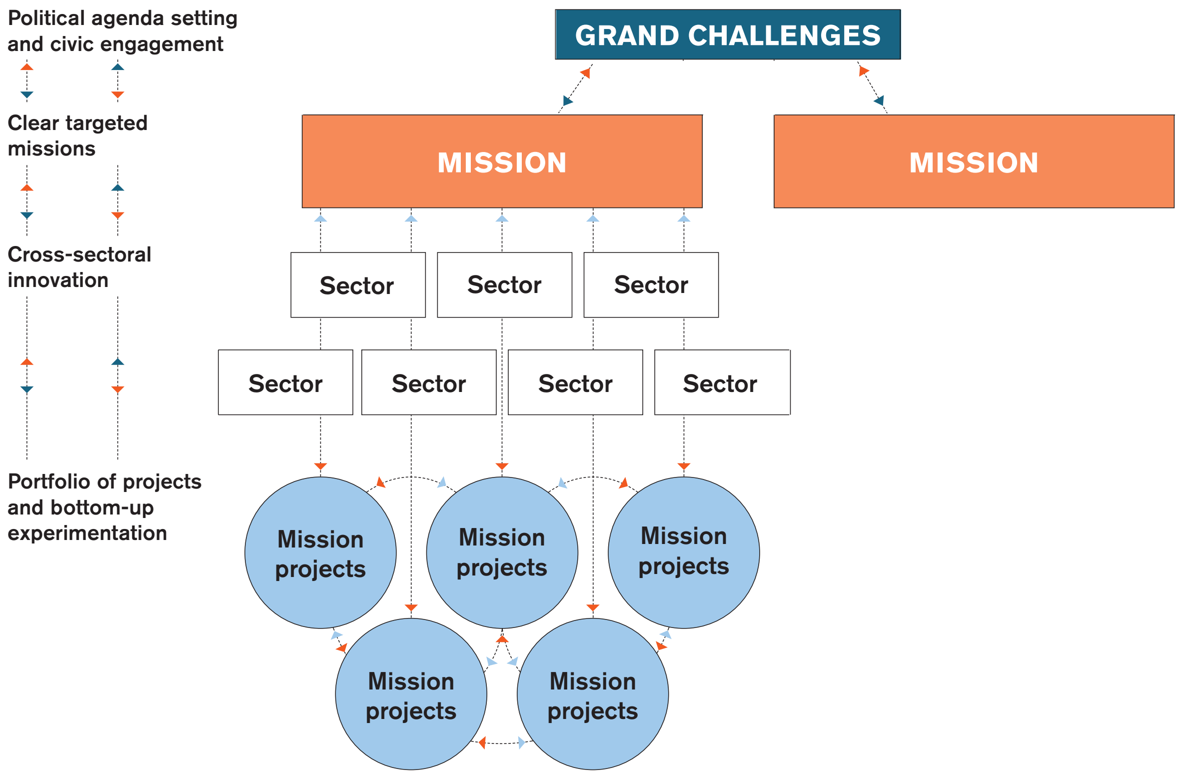
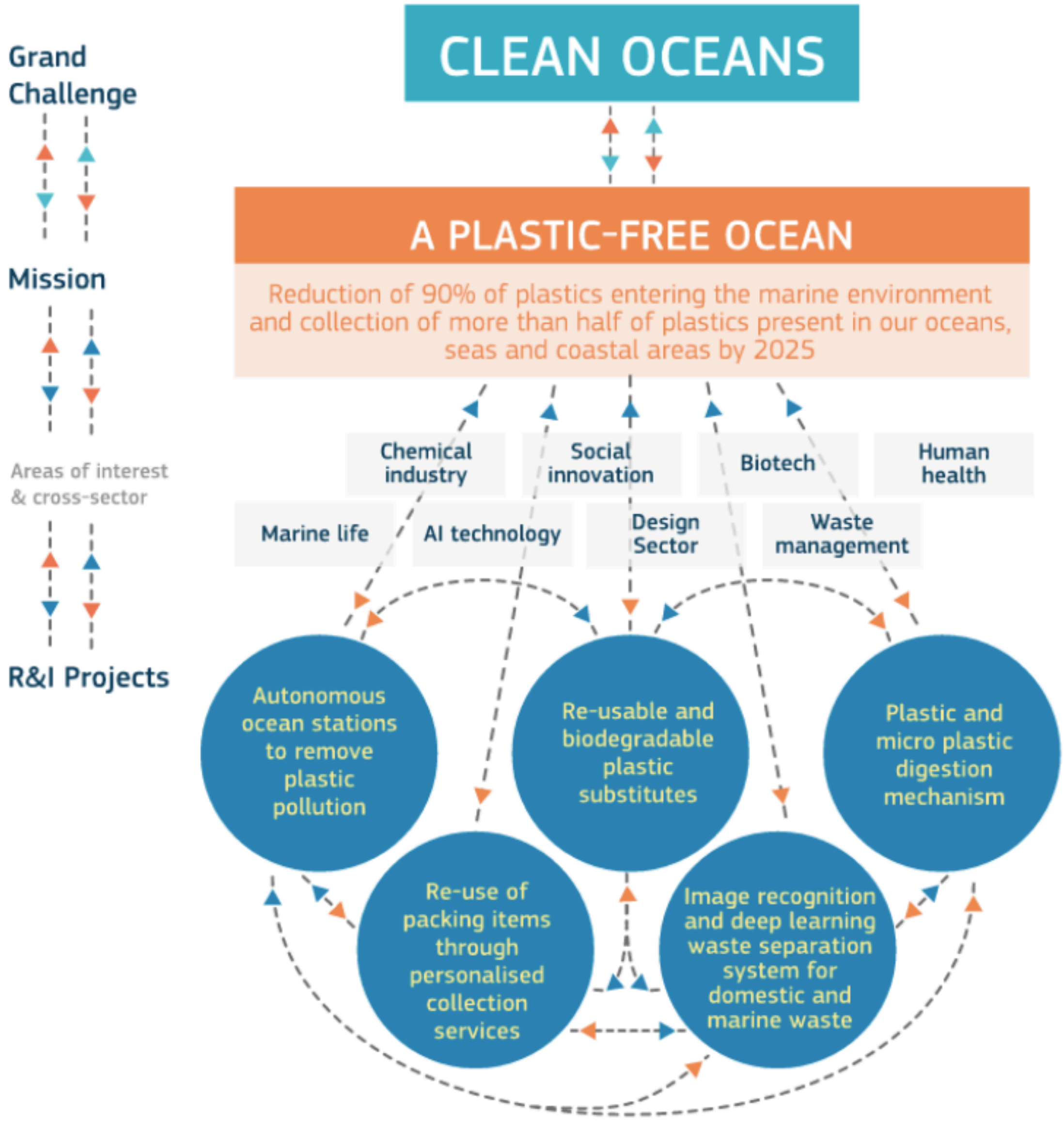


Figure 2. A mission-oriented approach to cleaning the oceans



Source: Mazzucato (2018a).

2. What innovation for missions?

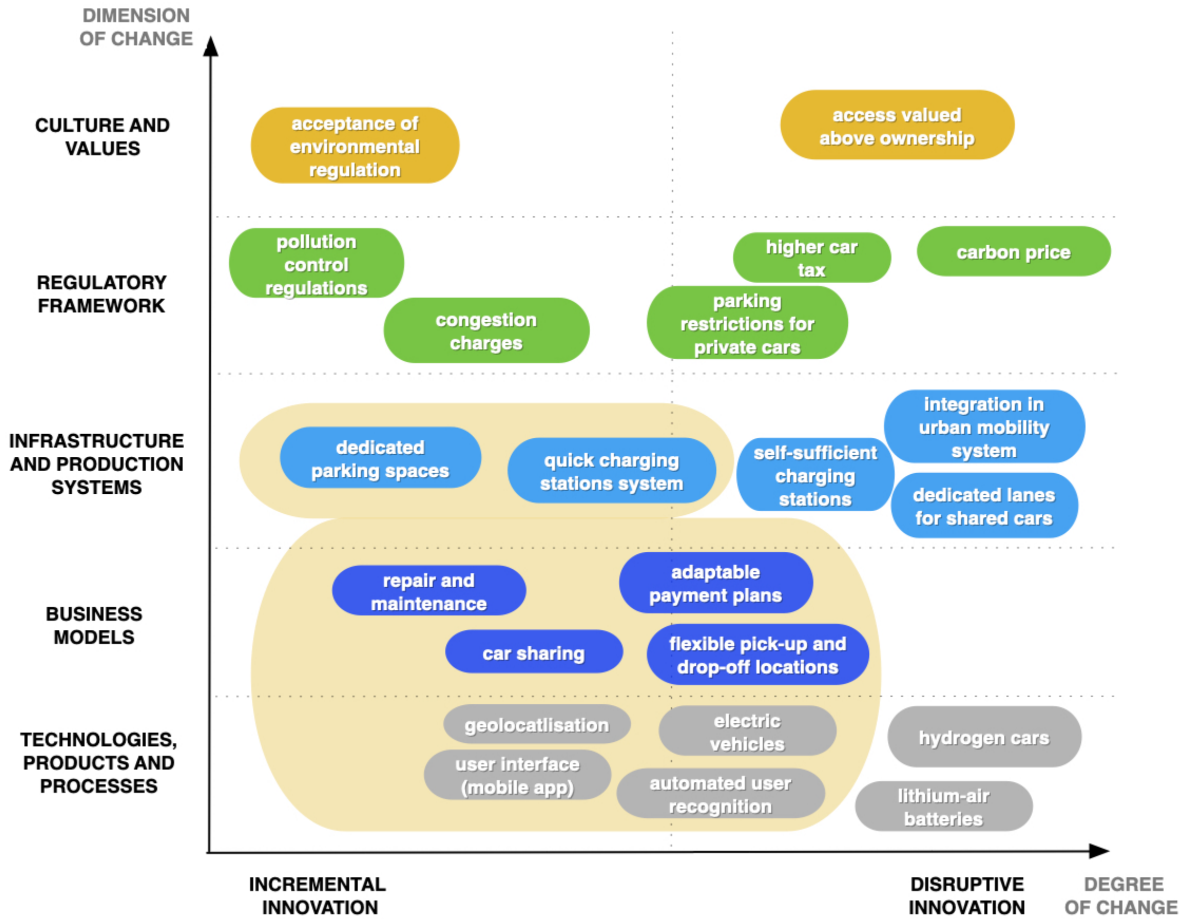
The challenges underpinning missions are complex, multidimensional, dynamic and uncertain in the long run. A reflection is needed about what kinds of innovation, and what 'innovation mixes' or 'innovation portfolios', have the highest potential to achieve transformative impact to accomplish missions that contribute to the SDGs. Our thinking about systemic change benefits from several perspectives on innovation and socio-technical transition rooted mainly in evolutionary economics and systems thinking. These include various schools of thinking about innovation systems (Lundvall, 1985; Freeman, 1995; Hekkert et al., 2007; Bergek et al., 2008), socio-technical systems and transitions (Rotmans et al., 2001; Geels, 2005), and innovation and technology management (Tidd and Bessant, 2013), as well as more recent perspectives on transformative innovation policy (Mazzucato, 2016; Kattel and Mazzucato, 2018; Schot and Steinmueller, 2018).

Innovation mixes for missions addressing the SDGs will need to include a wide variety of often interconnected technological and non-technological innovations. Missions can benefit from tested solutions to respond to urgent problems in the short term, but they also need ambitious innovations with the potential to disrupt and transform entire systems of production and consumption towards sustainability in a longer term. The latter approaches are to challenge dominant business models, redesign socio-technical systems, change urban and rural landscapes, and experiment with new governance and policy frameworks (Steward 2008; Kemp 2011). The objective of systemic transformation, or even system disruption, means that the process of prioritising the specific objectives and targets of missions goes beyond technological choices, and requires normative and political deliberation.

Innovations with a transformative impact are likely to be system innovations. System innovation is a portfolio of interdependent and mutually reinforcing innovations which together have a potential to transform systems delivering key services to societies, such as health, food, or mobility. The impact of system innovations depends to a large extent on the strength of synergies between its elements rather than only on the disruptiveness of individual technologies or products. Integrated urban mobility systems, for example, rely on combinations and synergies of product, service, organisational and process innovations, and infrastructural investments, as well as changes in regulatory framework (see Figure 3).

The assumption underpinning this approach is that, despite the complexities, uncertainties and serendipity inherent in innovation activities, system innovations can be *collectively* imagined, co-designed and orchestrated. System innovation thinking can be seen as a framework to offer a shared direction and seek new synergies between often disconnected innovation activities pursued by different actors in various sectors and different locations.

Figure 3. An electric car sharing model as a system innovation



- The core elements of an electric car sharing model are highlighted in yellow.
- The model can be extended and scaled by establishing links with additional innovations across various dimensions, and further enabled by favourable shifts in regulatory framework and value systems.
- The level of impact of the scheme will depend on combinations of various innovations and shifts in different dimensions.

Source: Miedzinski (2017)

Mission-oriented system innovation is about seeking alignment and synergies between innovations which, together, have a potential to accomplish the missions. The choices between alternative innovation pathways towards achieving mission objectives are difficult, and may even evoke controversy and conflicting views. Missions have to go beyond technical and technological domain, and require normative choices from involved actors (Miedzinski et al., 2018). Therefore, a missions-oriented approach to system innovation needs new approaches and mechanisms to innovation collaboration, social learning and deliberative governance. It is not about devising a controllable top-down intervention, but rather about creating mission-oriented innovation spaces, where experimentation and demonstration can be initiated and scaled, and stakeholder participation encouraged (Mazzucato, 2018b; Kattel and Mazzucato, 2018).

3. Policy mix and governance of mission-driven policies

3.1 Policy mix and governance of mission-oriented policies

Research and innovation policy for missions needs to provide incentives for actors to engage in innovation activities towards the mission objectives. To lead to transformative impacts and ensure a shared direction of travel towards mission objectives, missions need to be supported by a favourable policy mix and policy portfolios designed and implemented in a systemic and coherent manner on both the national and international level.

Policy mixes are 'complex arrangements of multiple goals and means which, in many cases, have developed incrementally over many years' (Kern and Howlett, 2009). In the policy mix perspective, policy instruments are considered within the wider governance, institutional and political context in which they are designed and implemented. Rogge and Reichardt (2016) argue policy mixes responding to major sustainability challenges need to consider complexity and uncertainty of societal transitions. Governance of mission-oriented policies also needs to acknowledge all relevant levels of governance at which support for innovation can be deployed.

Providing support for key mission-oriented innovations for the SDGs will require old and new forms of international policy collaboration and coordination encompassing various forms of public-public, public-private and private-private partnerships. International collaboration is necessary to improve international policy coherence and see synergy between instruments (e.g. by opening research and innovation funds to international consortia), as well as, on other hand, actively creating 'policy spaces' for new mission-oriented policy initiatives (e.g. cross-border initiatives for value redistribution across global value chains). This section discusses the characteristics of policy mixes and governance mechanisms relevant for a mission-driven approach (see also Miedzinski and McDowall, 2018).

Directionality

One of the key aspects of policy mixes supporting missions is whether, and to what extent, they provide incentives for stakeholders to engage in, and invest in, innovation activities contributing to a desired direction of change in a long run. Policy directionality refers to the shared vision and direction-guiding design and implementation of policy interventions towards a desired transformative change (Weber and Rohracher, 2012; Reichardt and Rogge, 2016).

Directionality can be introduced to a policy mix by identifying major challenges in policy visions and setting specific policy goals, milestones and targets, as well as translating those goals into concrete criteria guiding prioritisation of investment and policy implementation (Mazzucato, 2019b; Mazzucato and Perez 2015). Apart from providing positive incentives, policies can introduce negative incentives or restrictions. This is key for social and environmental sustainability objectives where markets left alone fail. Botta and Kozluk (2014) define stringency as the 'cost' imposed on polluting or other environmentally harmful activity. They argue that stringency can be analysed in relation to one instrument (e.g. regulation) and to the whole policy mix. Stringency is usually considered to have a positive impact on innovation (Rogge et al., 2011; Schmidt et al., 2012; Botta and Kozluk, 2014). Rogge et al. (2011) find that the innovation impact of the EU

Emissions Trade System (ETS) has been limited because of the scheme's initial lack of stringency. Based on their empirical study of firms' perceptions of EU ETS, Schmidt et al. (2012) argue that policy stringency is a critical element of a policy mix that can steer the rate and direction of technological change towards low-carbon technologies.

Missions are instrumental in introducing long-term directionality to the policy mix as they target concrete challenges and turn them into explicit socially relevant goals (Mazzucato, 2018a/b). In mission-oriented policies directionality means recognising mission objectives and targets as a central element of policy, and more concretely integrating them into specific objectives, targets and the implementation criteria of policy portfolios and programmes.

Mazzucato and Perez (2018) discuss the need for directed innovation to benefit from policy instruments that *tilt the playing field* rather than level it. In the case of missions that target a green transition, this would include, for example, using the taxation system to tax materials more than labour, as well as 'conditionality' so that businesses must reinvest their profits into particular areas (openly defined) in order to access public subsidies, guarantees and investments (Mazzucato, 2018b). Thus tilting is not about picking winners but *picking the willing* (Mazzucato, 2018b).

Comprehensiveness, coherence, consistency and coordination

Comprehensiveness is considered one of the key characteristics of a policy mix for sustainability transitions (Rogge and Reichardt, 2016). Missions will require a comprehensive policy mix comprising many mutually supporting instruments, and a different approach to designing, implementing and evaluating policies. A comprehensive policy mix is characterised by, first, an instrument mix including complementary types of instruments (e.g. market pull, technology push and systemic instruments) and, second, by policy processes and governance mechanisms (notably coordination, learning and collaboration) that enable such a systemic approach (see Figure 5). Comprehensiveness relies on strong policy capacities (Karo and Kattel 2018; Kattel and Mazzucato, 2018).

Numerous studies call for increased consistency and coherence of policy mixes supporting innovation for sustainable development (Foxon et al., 2004; Kemp and Rotmans, 2005; Foxon and Pearson, 2008; Reid and Miedzinski, 2008; Kemp, 2011; Rogge and Reichardt, 2016). The need to study consistency and coherence rests on the assumption that improved consistency of policy instruments and better coherence of policy processes can contribute to the higher effectiveness and efficiency of a policy mix. Failure to ensure consistency and coherence may result in decreased effectiveness or give rise to unintended effects, called 'escape routes' (Van den Bergh, 2013) or rebound effects (Vivanco et al., 2015). A similar logic applies to mission-oriented policies and portfolios.

Consistency, coherence and coordination are different elements of policy integration (OECD, 2003). Policy consistency means ensuring that individual policies are not internally contradictory. Policy coordination means getting the various institutional and managerial systems, which formulate policy, to work together. Policy coherence goes beyond coordination and consistency, and is defined as a process of 'ensuring the systematic promotion of mutually reinforcing action, by the concerned government and non-government players, in order to create and maintain synergies towards achieving the defined objective' (ibid). Policy coherence is not possible without striving for internal consistency and improving mechanisms of policy coordination. The challenge of policy coherence becomes particularly important for policies with an ambition to enable cross-sectoral and multi-actor innovation for sustainable development (Reid and Miedzinski, 2008; Rogge and Reichardt, 2016).

OECD (2003) differentiates between three types of policy coherence: horizontal, vertical and temporal. Horizontal coherence is to ensure that individual objectives and instruments developed by various entities are mutually reinforcing. Strengthening the inter-connectedness of policies and promoting a 'whole-of-government' perspective are ways of promoting horizontal coherence. The challenges addressed by missions require that governments cooperate internally across different ministries and departments responsible for different policy fields, as well as externally engaging key social and economic partners in the policy process (Kattel and Mazzucato, 2018).

Vertical coherence is about ensuring that the practices of various government bodies, agencies and autonomous bodies implementing policies at different levels of governance are aligned with overall policy commitments and are mutually reinforcing. For missions tackling global challenges, vertical coherence is about aligning approaches and initiatives at international, supranational, national and sub-national levels of government. The subsidiarity principle, understood as designing and implementing strategies and policy instruments at the most appropriate level, can help in ensuring vertical policy coherence (Reid and Miedzinski, 2008) and become relevant in the context of identifying the most effective governance arrangements to accomplish missions.

Temporal coherence is to ensure that policies continue to be effective over time and that longer-term commitments are not contradicted by short-term decisions. Temporal coherence is also about how policies work out as they interact with other policies or other forces in society, including whether future costs are considered in today's policy making. This is probably the most challenging task in the process of developing and implementing mission-oriented policies, as it includes long-term sustainability goals which may be perceived as opposed to short-term economic ambitions. The transition management approach (Kemp and Rotmans, 2005) is an example of an approach which accommodates both long- and short-term action.

A perfect overall policy consistency and coherence may be impossible to achieve due to inherent differences between objectives of various instruments and actors involved in the process (Carbone, 2008; Rogge and Reichardt, 2016). Policy makers need to recognise the complexity of 'real world policy mixes' and adapt their strategies accordingly (Flanagan et al., 2011). Howlett and Rayner (2013) point to two approaches to policy design that aims at the increased consistency and coherence of a policy mix: policy packaging or policy patching. Policy packaging refers to a policy design process in which previous policies are discarded and a new policy package is introduced. Policy patching refers to a gradual change of policies. They liken this to upgrading operating systems where 'software designers issue "patches" for their operating systems and programmes in order to correct flaws or allow them to adapt to changing circumstances' (ibid). They consider policy patching a more realistic policy strategy for improving the consistency and coherence of a policy mix.

Introducing mission orientation to the policy mix may be a rare chance to design coherent policy portfolios for missions. The political focus on missions could open up a window of opportunity for mission-specific policy packaging. The limitation of such an approach is that mission portfolios would have to be aligned with – or 'patched onto' – wider regulations and policy mixes which could undermine or even contradict mission objectives (e.g. environmentally harmful subsidies). With favourable political support, however, lessons from the implementation of mission-oriented policy portfolios could lead to gradual adaptation of wider policy mixes, and prepare the ground for a new policy and governance paradigm or 'operating system'.

Stakeholder alignment and mission partnerships

Working closely with stakeholders in designing and implementing mission-oriented policy is key to ensure a greater buy-in, and commitments to invest and act towards mission objectives. In order to achieve impact, missions should be co-designed with stakeholders willing to act as change agents. Without strategic alignments and partnerships around mission objectives, policy interventions are likely to fall short of meeting the ambitious goals of missions.

Seeking stakeholder alignment is particularly important for missions with an ambition to enable transformative system innovations. System innovation 'aims to achieve much more than coherence or policy alignment since it involves actors outside government, notably firms and civil society, and takes a longer-term view' (OECD, 2015). This points to the importance of building new partnerships supporting the desired direction of change and is key for a mission-oriented approach. With their transformative ambition, missions are likely to require radical reconfigurations of value chains and innovation collaborations across national borders and continents. Policy makers have to be mindful of the variety of strategic measures and instruments they can use to incentivise new innovation collaborations and joint investments, and disincentivise activities and investments deemed socially and environmentally harmful.

Forging new partnerships for system innovation may meet with fierce opposition from actors who may lose economic or political power because of the proposed direction of change. The recognition of the role of different types of incentives guiding strategic investment decisions and the innovation activities of key stakeholders will be key for the process of mission-oriented policy roadmapping.

Experimentation culture and learning

Key to the success of directed policies is making sure that direction setting does not stifle bottom up experimentation. In this sense, it is key that instruments like procurement and prize schemes are used to welcome multiple solutions, experimentation and exploration (Kattel and Mazzucato, 2018).

Experimentation and policy learning are key features of ambitious policy supporting transformative innovation. Kattel and Mazzucato (2018) argue that this requires new types of dynamic capabilities inside public institutions that enable them to learn and experiment, similar to the 'dynamic capabilities of the firm' and absorptive capacity in the private sector (Teece and Pisano 1994). Schot and Steinmueller (2016) argue that transformative innovation policy should enable experimentation with options 'beyond the narrow boundaries set by incumbents'. This embedded approach to experimentation is inspired by, for example, Strategic Niche Management (SNM) (Kemp et al., 1998) which argues that 'sustainable innovation journeys can be facilitated by modulating of technological niches, i.e. protected spaces that allow nurturing and experimentation with the co-evolution of technology, user practices, and regulatory structures' (Schot and Geels, 2008).

In a similar vein, Mazzucato (2013; 2016; 2018b) argues that market shaping policies must not only go beyond fixing markets, but must be able and willing to redefine the market outside of only profitable areas. For example, in the areas of health, publicly funded innovation has been too focussed on pharmaceuticals and too little on health living, resulting in the 'pharmaceuticalization' of the health sector (Abraham, 2010). Redefining the market would put more science funding emphasis on preventative care including healthy living and dignostics.

Experimentation is key for ensuring diversity, learning and network development. At the same time, however, too much diversity may hamper innovation by fragmenting investments, generating uncertainty and risk, and slowing down the emergence of stable rules (Dosi, 1982; Schot and Geels, 2008). In order to be transformative and not end up as isolated single experiments, experimentation needs to be embedded in policy mixes, and be given a dedicated space in regulatory, organisational and institutional frameworks (Nelson and Winter, 2002; Chataway et al., 2017).

The nature of evidence needed to support long-term mission-oriented policies is different from the evidence base of short-term decisions. Rather than relying only on formal monitoring and evaluation, the policy process should become an ongoing policy learning process, including experimentation and embracing complexity and uncertainty of transitions. Policy learning can become a process which mediates an agreement between stakeholders on what is 'sufficiently robust' evidence for the shared vision and preferred courses of action (Miedzinski 2015; 2018).

Credibility and long-term commitments

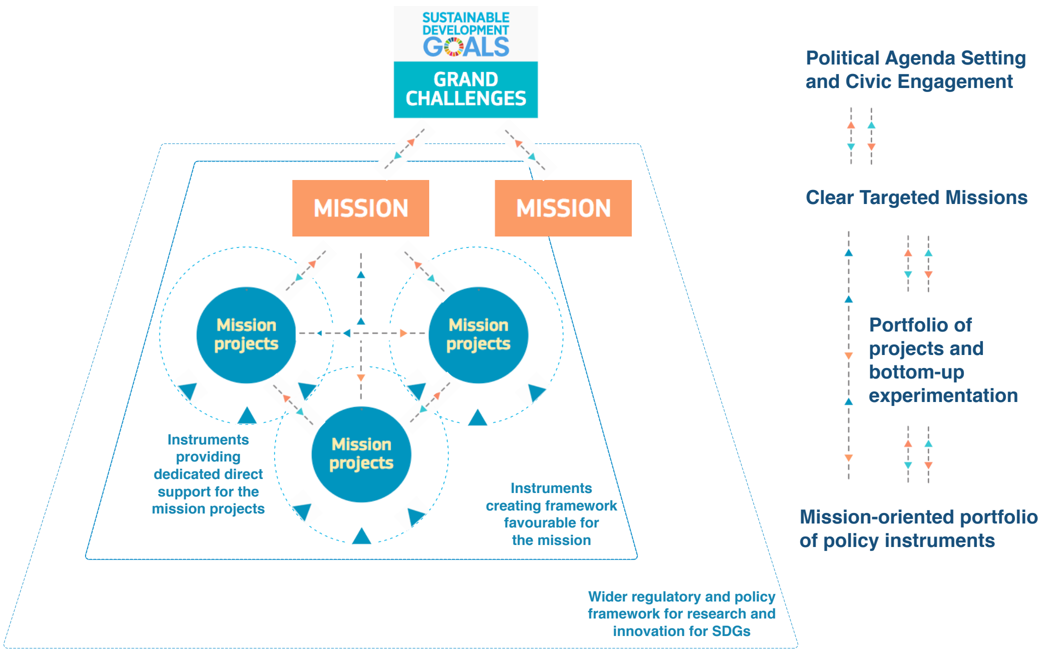
Ensuring the stability of goals and targets supported by a policy mix is important for mobilising stakeholders, notably investors, around policy objectives. A stable policy environment with a common 'direction of travel' is important for policy credibility. Rogge and Reichardt (2016) define credibility as 'the extent to which the policy mix is believable and reliable, both overall and regarding its elements and processes'. Credibility may be positively or negatively influenced by a range of factors, including the commitment from political leadership, a consistent and coherent policy mix, introduction of formal targets, competences of public administration or effective coordination between ministries and agencies. Various mechanisms have been proposed to bolster the credibility of policy measures. Levin et al. (2012) and Brunner et al. (2012) suggest a number of ways in which policies can be made 'sticky', i.e. difficult to change. Governance arrangements around the UK Climate Change Act 2008, which included the establishment of legislated carbon budgets and the creation of a statutory body (the Committee on Climate Change) to report on government progress, provide an example of an attempt to embed some of these principles into UK climate policy.

The important role of the perceived credibility of a policy mix by stakeholders has been confirmed by a number of empirical studies. For example, Bödeker and Rogge (2014) conducted a case study of solar PV in Germany based on content analysis of the industry journal *Photon* (1996–2012). The analysis suggests that the most relevant determinants of the perceived policy credibility were the stability and temporal consistency of the policy mix, and the commitment from political leadership. In their study on the German off-shore wind sector, Reichardt and Rogge (2016) found that the consistency and credibility of the policy mix were important incentives for low-carbon innovation. The results suggested that political credibility and stability could temporarily compensate for the lack of consistency and comprehensiveness of the instrument mix. In the UK, Uyarra et al. (2016) reported that the concerns about the policy coherence and consistency led to a questioning of policy credibility, which might negatively influence innovation activities by SMEs active in low-carbon innovation.

3.2 Innovative policy portfolios and instruments for mission-oriented policies

The new framing and features of policies oriented towards missions need to be reflected in the selection, design and implementation of policy instruments and policy portfolios. Missions can be supported directly (e.g. public finance) or indirectly by policy instruments creating a favourable environment for the innovations needed to achieve the missions (Figure 4). STI policy instruments can be designed to contribute to specific missions by re-adjusting their objectives and design features (e.g. targets, criteria). The choice of instruments for policy portfolios will differ depending on the type, maturity, and level of disruptiveness of supported innovation, as well as the innovation capacity of the actors targeted by direct or indirect policy support.

Figure 4. Building mission-oriented policy portfolios



Source: Authors based on Mazzucato (2017)

Figure 5 outlines how various policy instruments can contribute to the mission-oriented policy approach. While adaptations of existing instruments and portfolios are important, it is key to ask whether these changes are sufficient, and whether there is a need for new or significantly redesigned policy portfolios and innovative policy instruments, and governance processes, to deliver on the transformative ambition of mission-oriented innovation policy and the 2030 Agenda.

This paper also argues that mission-oriented policies for the SDGs require mission-oriented policy portfolios, as well as dedicated systemic policy instruments, to provide an overarching strategic framework for the design and implementation of portfolios over long time periods. The need to address the long-term challenges underpinning missions requires 'framework instruments' which combine activities known from strategic foresight, planning and design, and policy implementation. The function of these new instruments is to develop and sustain a strategic framework for action that mobilises stakeholders and investments in missions, and ensures directionality and coherence of mission-oriented policy portfolios until the mission's objectives are accomplished.

Figure 5. Policy instruments for mission-oriented innovation policies

Category	Relevance for mission-oriented policies
Policy instrument	
Direct financial support	
Institutional funding for public research organisations (universities & research institutes)	Funding for research contributing to missions, including blue sky research
Project grants for public research organisations	Funding for research contributing to missions, including blue sky research
Grants for business R&D and innovation	Grants to businesses for R&D and innovation relevant for missions
Centres of excellence grants	Centres fully or partially dedicated to missions
Procurement programmes for R&D on innovation	Funding for procurement encouraging innovation, scaling up and diffusion relevant for missions; procurement with specific criteria encouraging innovation addressing missions including innovation, pre-commercial and functional procurement.
Fellowships and postgraduate loans and scholarships	Funding for fellowships and postgraduate loans and scholarships explicitly focused on missions.
Loans and credits for innovation in firms	Funding for loans and credits for innovation relevant for missions.
Public finance	Public funding for loans and credits for innovation relevant for missions (e.g. public investments, development loans, guarantees), including "patient finance"
Feed-in Tariffs	Payments to the outcomes generated by innovations relevant for missions (often applied to renewable energy technologies).
Equity financing	Public funds for venture capital and other forms of equity financing spent on innovative projects relevant for missions.
Innovation vouchers	Funding for innovation vouchers for innovative mission projects.
Indirect financial support	
Corporate tax relief for R&D and innovation	Tax relief for R&D and innovation relevant for missions.
Tax relief for households for R&D or adoption of innovation	Tax relief to households for the promotion of innovative goods and services relevant for accomplishing missions
Debt guarantees and risk sharing schemes	Debt guarantees and risk sharing schemes with preferential conditions for investments relevant for accomplishing missions.
Tax on environmentally-harmful technologies	Levy or tax on harmful products or technologies which counteract mission objectives.

Category	Relevance for mission-oriented policies
Policy instrument	
Technology guidance and advisory services	
Technology transfer and business advisory services	Centres and funding for international, national or regional technology transfer and business advisory services that are fully or partly focused on missions and business advisory services for innovative businesses focused on areas relevant for missions.
Business incubation advice	Centres and level of funding for business incubation advice that is fully or partly focused on missions.
Collaborative platforms and infrastructure	
Clusters and other networking and collaborative platforms	Funding for programmes to support clusters and other networks and collaborative platforms specifically focused on missions.
Dedicated support to new research infrastructure	Funding for new research infrastructure of relevance to research and demonstration relevant for accomplishing missions (e.g. materials testing facilities, emission testing facilities, toxicity testing labs)
Information services and databases	Funding for information services and databases focused on mission-oriented innovation and/or addressed to innovative companies and other stakeholders active in areas relevant for missions.
Governance and regulatory framework	
National strategies, agendas and plans	Strategies, agendas and plans fully or partly focused on missions.
Policy roadmaps and long-term action plans*	Processes to co-design and coordinate mission-oriented innovation policy portfolios with dedicated targets and milestones. Roadmaps can provide frameworks for national and international collaboration.
Creation or reform of governance structures or public bodies	Governance structures or public bodies with specific mandates and tasks related to missions.
Policy intelligence (e.g. evaluation, foresight)	Thematic evaluations and foresights focused on missions.
Consultation of stakeholders and experts	Formal consultations of stakeholders with a focus on missions.
Horizontal STI coordination bodies	STI coordination bodies that explicitly recognise the role of mission-oriented innovation in horizontal STI (e.g. adding topics related to missions to agendas of STI councils or committees).
Product and process standards and certification	Examples include performance standards relevant for missions for appliances, equipment, and buildings.
Labour mobility regulation and incentives	Labour mobility regulations and incentives designed to encourage mobility of staff with competences relevant for missions
Intellectual property regulation and incentives	Funding for intellectual property regulation and incentives with a specific focus on technologies and solutions relevant for missions (e.g. promoting open access to IP or supporting young firms).
Public awareness campaigns and other outreach activities	Funding for instruments to increase mission-oriented knowledge, awareness and training among stakeholders or the general public (information campaigns, training programmes, labelling schemes).
Science and innovation challenges, prizes and awards	Funding for S&T challenges, prizes and awards focused on mission challenges (e.g. prizes for mission innovations)

Source: Authors, based on Miedzinski M., Kemp R. and Türkeli S. (2018). Policies for eco-innovation and green economy. In: R. Kemp et al., *Maastricht Manual on Measuring Eco-Innovation for a Green Economy*. Deliverable 2.5 of H2020 green.eu project. Policy taxonomy adapted from EC-OECD STI Policy Survey (2017). *Added by authors.

Design of policy portfolios should consider how various policy instruments can incentivise actors with different needs and capacity, and leverage and funnel the investments in innovation needed to accomplish the SDGs. For example, a portfolio of financial instruments catered for different business actors could include: 'patient finance' from entities like public banks to provide long-term investments for large companies and consortia; grants and innovation procurement funds to scale up small innovative companies; and venture capital funds to enable small start-ups and medium-sized scale-ups, as well as crowd funding for micro- and small companies, NGOs and grass-roots initiatives.

4. Towards a framework for mission-driven policy roadmapping

4.1 What is a roadmap?

Galvin (1998) considers a roadmap to be 'an extended look at the future of a chosen field of inquiry composed from collective knowledge and imagination of the brightest drivers of change in that field'. Roadmaps as a planning and management tool have been most often applied in innovation and technology management. Phaal et al. (2004: 9) defines technology roadmapping as 'a powerful technique for supporting technology management and planning, especially for exploring and communicating the dynamic linkages between technological resources, organizational objectives and the changing environment'. One distinctive feature of the concept is 'the use of a time-based structured (and often graphical) framework to develop, represent and communicate strategic plans, in terms of the co-evolution and development of technology, products and markets' (ibid: 10). Given the complexity involved, the roadmaps are often represented in a format that includes flowcharts, single- or multi-layer representations, bars, graphs or other images.

The framework and practice of technology roadmapping is based on several general features and practices which offer relevant lessons for any context (Phaal et al., 2004; Phaal and Muller, 2009):

- Roadmaps need to have an explicit purpose usually expressed as a vision and strategic priorities (i.e. they respond to the question 'where do we want to go?').
- The roadmap includes an explicit perspective of a time horizon and timelines illustrating the process of getting to the vision. The latter includes an explicit time horizon presented with the use of scales and intervals (i.e. 'how to get there?').
- Many roadmaps opt for presenting the transition towards the vision on various inter-related layers (e.g. product, sector or policy). The latter is to allow for anticipating and possibly managing the factors that may enable or hamper the transition process.
- The roadmapping process needs a reflection on the current state of development or a baseline (i.e. 'where are we now?').
- The development of roadmaps requires the active involvement of key stakeholders. The process can benefit from diverse inputs in terms of disciplines, functions, and levels within or from across various organisations, including external perspectives (Phaal and Muller 2009: 41). Whether the process is intra- or inter-organisational, the process should be seen as a learning and knowledge sharing exercise, and an approach to creating shared visions.

Despite being associated with technology management and business strategy in business, roadmapping as a planning and management technique has been applied to many topics in diverse contexts, including policy making (see Ahlqvist et al., 2014; Carayannis et al., 2016), and has been increasingly used in the context of large-scale transformative changes (McDowall, 2012). Most recently, roadmaps have been promoted as relevant STI policy instruments to support implementation of the 2030 Agenda and the SDGs on the international, national and regional levels. In this context, roadmaps are offered to STI policy makers as tools to enable formulation, planning and implementation of public policies, often in relation to long-term ambitious sustainability goals.

4.2 Conceptual framing of mission-oriented policy roadmap

This paper revisits the roadmapping technique and proposes redesigning it as a systemic policy instrument which can be employed to guide the design and implementation of mission-oriented innovation policy. There is a need for new policy mechanisms and governance arrangements to tackle missions which cut across national boundaries and sectors. The roadmapping technique appears to be a tool well suited to the policy context, in particular to ensure long-term directionality, consistency and coherence of policy portfolios. Before redesigning roadmapping as a systemic policy instrument, however, a reflection is due about which elements and aspects of the roadmapping technique, originally designed for and applied in industry, need to be rethought, reconfigured or added to be relevant for mission-oriented policy making.

Miedzinski et al. (2018) conducted a review of 20 national and international STI roadmaps relevant for sustainable development to evaluate their fitness to respond to the challenges of sustainability transitions and the SDGs. The analytical framework and criteria used in the analysis are directly relevant for a mission-oriented approach. Figure 6 summarises key implications of the review for the mission-oriented innovation policy roadmapping framework proposed in this paper.

Figure 6. Key characteristics of mission-oriented policy roadmaps addressing the SDGs

Area	Definition	Review questions	Relevance for mission-oriented policy roadmaps
Relevance and long-term directionality	The extent to which the vision and objectives of roadmaps are appropriate for sustainability challenges and the SDGs.	What is the main purpose and scope of roadmaps, and how do they relate to SDGs? What is the wider context in which roadmaps emerge?	Selected missions should be relevant and appropriate for sustainability challenges and the SDGs.
Roadmap design	The intervention logic and design of roadmaps to sufficiently reflect characteristics of sustainable development challenges.	What is the architecture of roadmaps, notably how they introduce visions, pathways (targets and milestones, layers etc,) and action plans?	Roadmap design should highlight dimensions of the transition, including different types of innovations, the role of different actors, and the instruments and governance mechanisms of transition.
Innovation	The level of ambition and aspiration of innovation promoted by roadmaps, including recognition of the role of experimentation and system innovation.	What types of innovation activity are roadmaps promoting to enable the sustainability transition? What is the level of ambition of innovation?	Mission-oriented policy roadmaps should focus on transformative innovation which potentially addresses the root of the problem.
Strategic specialisation	The extent to which roadmaps encourage innovation specialisation in the most relevant areas for sustainability.	Are roadmaps based on a strategic prioritisation process including existing and emerging areas of specialisation? Are roadmaps aiming at changing specialisation patterns to more effectively respond to sustainability challenges?	Mission-oriented policy roadmaps should balance consideration of a variety of innovation pathways ('opening up') with effective prioritisation.
Alignment	The extent to which roadmaps mobilise actors to align their strategies with the shared vision, and to engage in transformative innovation.	How are stakeholders consulted and engaged at different phases of the process?	Mission-oriented policy roadmaps should be co-designed with relevant stakeholders and encourage mission-oriented collaborations.
Actionability	The extent to which roadmaps are based on absorptive and implementation capacity of actors in the innovation system.	What are the mechanisms by which roadmaps are implemented?	Selection and scoping of missions should consider absorptive capacity of business and institutional capacity of government to implement the proposed priorities and actions.
Coherence	The extent to which roadmaps are internally coherent and coordinated with relevant policy mixes and with the SDGs.	How are roadmaps embedded into wider STI policy mixes?	Missions supported by policy roadmaps should be supported by coherent policy portfolios and be embedded in the broader policy mix.
Learning and adaptability	The extent to which roadmaps support learning and include mechanisms allowing for adaptation of its elements based on new evidence.	How is the implementation of roadmaps monitored and evaluated?	Mission-oriented policy roadmaps should include a dedicated monitoring and evaluation system, and governance arrangements supporting policy learning.

Source: Based on Miedzinski et al (2018); column on mission-driven policy roadmapping added by authors.

4.3 Architecture of mission-oriented policy roadmap for the SDGs

Mission-oriented policy roadmapping can help to ensure long-term directionality and coherence of an innovation policy response to the challenges posed by the SDGs. The proposed framework is based on a systemic and goal-oriented approach to innovation, and draws on the lessons from roadmapping practices in industry and policy. The main value added of the approach, however, is to adapt the roadmapping technique to make it useful for policy design and implementation processes. The proposed framework makes policy and governance layers integral elements of roadmaps.

The framework is organised into three layers:

Grand challenge and mission

- **Grand challenge:** This layer introduces evidence on historical trends and anticipated future scenarios relevant for the challenge and the mission.
- **Mission goals and targets:** This layer introduces specific goals and targets of missions. The goals and targets are key to tracking progress in accomplishing missions and to measure their contributions to the related SDGs.

Innovation pathways

- **Key innovations:** This layer is about innovations selected to meet the goals and targets of the mission. Our focus is on innovations with transformative potential. The pathways comprise deployment of existing technological and non-technological innovations, emerging radical innovations and business models, and untapped R&I opportunities which need further investment.
- **Enabling systems:** This layer is about identifying key elements and dynamics of the system needed to give direction to desirable innovation pathways and enable them to emerge, scale and diffuse. Our focus is, inter alia, on the absorptive capacity of firms, collaboration between actors in the innovation system, the policy and regulatory framework, private and public finance, and human and social capital, as well as technical and technological infrastructures. This layer identifies key sectors and areas of interest for the innovations such as value chains and regional hot spots.

Policy roadmap

- This layer results in a policy roadmap (or connected policy roadmaps) with short-term and longer-term actions to design and deploy policy instruments, crowd in investment from key stakeholders and support implementation of the mission.
- Policy roadmap focuses on three sub-layers: policy instruments, governance mechanisms and capacity, and policy learning to enable effective implementation of policy portfolios:
    - **Policy action plan:** This sub-layer is a strategic policy framework for action which comprises dedicated public and private strategies, instruments and actions oriented towards accomplishing mission objectives. Policy roadmaps seek synergies between actions providing direct support to innovation and creating favourable conditions for systemic cross-sectoral collaborations.

- **Governance:** This sub-layer focuses on designing, co-designing and installing new governance mechanisms to engage key stakeholders in implementation of the roadmap at different governance levels. Governance of mission-driven policy roadmaps should provide arenas for continuous deliberation and search for alignment between stakeholders who share the common objectives.
- **Capacity and policy learning:** This sub-layer comprises on-going reflection, monitoring and evaluation of the roadmap implementation, and adaptation mechanisms to adjust it to the changing context. Governance of mission-driven policy roadmaps should promote experimentation and demonstration.

The framework is designed to guide deliberation of mission-oriented policy roadmaps based on evidence and normative visions brought together by a process of co-design of innovation pathways and policy portfolios. Policy roadmaps may comprise many roadmaps, including, for example, a general framework roadmap and many specific roadmaps dedicated to key innovations, initiatives or localities. It can provide a framework for national policy and international collaborations, as well as local policy actions deemed key for accomplishing the mission.

The approach emphasises the role of experimentation and learning, which allows for building shared understanding of the risks, costs and benefits associated with alternative innovation pathways. The focus on engaging stakeholders and learning from the implementation of mission-oriented experiments is one way of dealing with the complexity and uncertainty of transitions. This approach is an alternative to technology-centric rationalistic policy planning.

The challenge is to link the proposed framework with existing strategies and policies (for example, National Development Plans in developing countries), notably with the strategic decisions prioritising specialisation areas with the expected high-impact potential for key missions and the SDGs. Examples of such approaches in the EU context include smart specialisation strategies. The framework could start up new, or connect with existing, mission-driven smart specialisation areas. It can provide spaces where relevant stakeholders can collectively deliberate on missions, and work out practical ways of sharing the risks and benefits of their investments. In the UK, stakeholders involved in the UCL-led MOIIS policy Commission developed roadmaps to implement missions for the UK Industrial Strategy (UCL Commission on Mission-Oriented Innovation and Industrial Strategy, 2019).

Figure 7 sketches out a framework with the three layers brought onto a typical roadmapping timeline.

Figure 7. Mission-oriented innovation policy roadmapping framework for the SDGs

<table>
<tr><th colspan="2"></th><th colspan="2">Where are we?</th><th colspan="3">How are we going to get there?</th><th>What do we want to achieve?</th></tr>
<tr><th colspan="2"></th><th>Past</th><th>Now</th><th>Short-term (2020)</th><th>Medium-term (2025)</th><th>Long-term (2030 and beyond)</th><th>Long-term objectives and targets</th></tr>
<tr><td rowspan="2">GRAND CHALLENGE AND MISSIONS</td><td>Grand challenge</td><td colspan="2">Collect evidence on systemic determinants and impacts of the grand challenge</td><td colspan="3">Indicate key metrics of systemic drivers and barriers, and impacts, of the grand challenge to monitor its evolution in short, medium and long-term</td><td>Identify the grand challenge to be addressed by the roadmap</td></tr>
<tr><td>Missions</td><td colspan="2">Identify evidence on systemic determinants and impacts of challenges specific for missions</td><td colspan="3">Agree on specific goals, milestones and targets for the mission
Identify links to the relevant SDG targets and to national and local goals
Agree on key indicators to track progress in the short, medium and long-term</td><td>Identify and select missions to be addressed by the roadmap</td></tr>
<tr><td rowspan="2">INNOVATION PATHWAYS</td><td>Key innovations</td><td colspan="2">Scan existing and emerging technological and non-technological innovations relevant for accomplishing the mission</td><td>Identify key STI needs relevant for the mission requiring public support in the short, medium and long term</td><td colspan="2" rowspan="2">Identify ley innovation strategies and prioritise “innovation portfolios” to be covered by the roadmap
Explore alternative innovation pathways and characterise enabling systems needed to accomplish the mission</td><td rowspan="2">Identify emerging and imagine new innovations and enabling systems needed to accomplish the mission</td></tr>
<tr><td>Enabling systems</td><td colspan="2">Analyse enabling systems relevant for the mission, including policy mix and institutions, business and finance, sectors and value chains, absorptive capacity, human capital.</td><td>Identify key incentives and barriers to innovations and changes needed to accomplish the mission</td></tr>
<tr><td rowspan="3">POLICY ROADMAP</td><td>Policy action plan</td><td colspan="2">Analyse policy impacts of historical and current policy interventions (meta-evaluation)</td><td colspan="3">Co-design a policy roadmap for the selected innovation portfolio
(agree and commit to concrete actions and set up specific goals and targets)
Design and compare alternative policy scenarios for the selected innovation portfolio (including costs and benefits of policy options)</td><td>Imagine a policy mix favourable for missions</td></tr>
<tr><td>Governance</td><td colspan="2">Map and analyse governance structures, incentive systems and change mechanisms relevant for the mission</td><td colspan="3">Co-design governance structures, incentive systems and mechanisms assisting continuous implementation and adaptation of the policy roadmap
Ensure that governance arrangements underpin the continuous search of alignment between key stakeholders who share the common objectives.</td><td>Imagine governance mechanisms and an institutional setting favourable for missions</td></tr>
<tr><td>Learning and capacity building</td><td colspan="2">Assess institutional capacity to design, implement and evaluate relevant policy</td><td colspan="3">Prepare an action plan to accompany the roadmap including actions to enable learning, capacity building and roadmap adaptation processes
Set up monitoring and evaluation system to measure progress towards the specific goals and targets of the mission
Conduct experimentation and demonstration projects</td><td>Imagine competences and a learning environment favourable for missions</td></tr>
</table>

Legend: The framework can be used as an analytical tool for assessing existing roadmaps as well as a strategic framework for formulating and implementing mission-driven innovation policy roadmaps. The framework assumes that mission-driven policy roadmapping is a participatory process. When applied to specific societal challenges and missions in specific contexts the framework should be adapted to focus on relevant aspects. The exercise should allow for iterations between horizonal layers and temporal segments (e.g. the selection of key technology areas and innovations to be supported by policy has to consider not only the expected impact of these innovations but also the policy capacity to implement effective policy intervention).

5. Implementation of the mission-driven policy roadmapping process

We propose to implement the mission-driven roadmapping framework following six steps:

- **Step 1. Scoping**: Identify a challenge and mission to be addressed by the roadmap
- **Step 2. Baseline**: Conduct baseline analysis for the mission
- **Step 3. Vision and goals**: Create a vision and set up goals and targets for the mission
- **Step 4. Innovation pathways**: Select innovation pathways to accomplish the mission
- **Step 5. Policy roadmap**: Co-design a mission-driven policy roadmap
- **Step 6. Policy learning**: Ensure ongoing reflection and policy action learning.

Figure 8. Steps in the mission-oriented innovation policy roadmapping for the SDGs

Step	Objectives	Duration (≈)
Step 1. Scoping	• Agree on a broad challenge and mission to be addressed by the roadmap. • Relate the selected mission to the SDGs and the SDG targets. • Engage key stakeholders committed to the mission. • Secure necessary resources for the roadmapping process. • Agree on the organisation and governance of the exercise.	1-3 months
Step 2. Baseline	• Review existing scientific evidence on the selected problem. • Create an impact map: Analyse the causal mechanisms and dynamics of impact pathways related to the addressed challenge; Identify the root causes of the problem and list the primary impact hot spots. Map the SDGs and the SDG targets onto the impact hot spots, indicating causal links with their key targets onto the impact map. • Map the innovation landscape: Identify and categorise existing and emerging innovations for the mission, and relate them to the 'hot spots', the SDGs and the SDG targets. • Map policy landscape: Identify and categorise the current policy mix and key non-governmental initiatives relevant for the mission, and relate them to the 'hot spots', the SDGs and the SDG targets.	3-6 months
Step 3. Vision and goals	• Co-create a shared vision for the mission. • Agree on the main objectives, targets and the time horizon for the roadmap, explicitly linking them to the impact hot spots. • Agree on the interim objectives of the roadmapping process.	1-3 months
Step 4. Innovation pathways	• Explore alternative innovation pathways for addressing the impact 'hot spots' and for accomplishing the mission. • Identify the drivers, enabling factors and barriers of research and innovation (R&I), including market and system failures, that require adaptation to enable mission-oriented R&I. • Choose the 'innovation mix' to be supported by the roadmap. • Select portfolios of R&I projects (including experimentation and demonstration) to support the 'innovation mix' to achieve impacts on the targeted 'hot spots' in the short, medium and long term. • Agree on expected timelines of implementation by indicating lead times to impact of research and innovation projects.	3-6 months
Step 5. Policy roadmap	• Explore key policy instruments and policy portfolios to provide direct and indirect support to the selected innovations. • Co-design a long-term policy roadmap with goals, targets and timelines of action (including instrument sequencing) led by public and private actors in the short, medium and long term. • Assign short and medium-term actions to stakeholders, notably on experimentation and demonstration projects for the mission. • Agree on indicators for monitoring and evaluation of the roadmap. • Prepare the short-term policy action plan introducing the governance and implementation process of the roadmap.	3-6 months
Step 6. Policy learning	• Set up governance mechanisms and build a policy learning environment supporting the implementation and ongoing reflection on the roadmap. • Establish dedicated capacity building processes and design a learning environment for stakeholders involved in the roadmap.	Ongoing

Annex I elaborates objectives, activities, methods and tools proposed for each step.

6. The illustrative case of 'A Plastic-Free Ocean' mission

6.1 Introduction

This chapter introduces an illustrative application of the framework to 'A Plastic-free Ocean' mission presented as an example in the EC report on mission-oriented policy (Mazzucato, 2018). The purpose is to tentatively illustrate and discuss how the logic and steps of the mission-oriented policy roadmapping process can be applied to a specific challenge. This section focuses on the first two steps of the process, i.e. scoping and baseline analysis. The deliberative steps of the process (3-6) are introduced briefly as they are designed to be developed in close collaboration with stakeholders.

6.2 Step 1: Scoping 'A Plastic-Free Ocean' mission

Marine plastic pollution is a global and widespread problem recognised as a 'cross-cutting crisis' causally linked and virtually inseparable from all major environmental sustainability challenges, including climate change, biodiversity loss and food security, as well as risks to human, animal and ecosystem health (Borrelle et al., 2017; Vince and Stoett, 2018). Marine plastic pollution is a good example of a complex issue with direct or indirect links to all SDGs and many SDG targets.

Marine plastic pollution has gained unprecedented attention worldwide. There is a global consensus about the urgency and importance of the challenge, and many international and local initiatives are targeting the challenge. Marine plastic pollution has become recognised by governments, international organisations, business and civil society. The marine litter crisis has been addressed by many international initiatives, such as the UN Global Partnership on Marine Litter and the action plans of the G7 and G20.

In 2016, the second United Nations Environment Assembly (UNEA) adopted a resolution which requests all countries to 'raise awareness of the sources and negative effects and possible measures for reducing marine plastic debris and microplastics; to promote change in individual and corporate behaviour; and to cooperate in the prevention and clean-up of marine plastic debris.' In 2017, the UN General Assembly adopted a Ministerial Declaration by consensus that reinforced this resolution. The mission is closely aligned with *A European Strategy for Plastics in a Circular Economy* (EC 2018), which identified plastic waste leakage into the oceans as one of key challenges and opportunities for a circular economy. A mission-oriented policy roadmap can contribute additional value to this wider policy context.

The scope and ambition of the mission-oriented innovation roadmapping process depends on the initial commitment and resources made available by key stakeholders. The process should mobilise various stakeholders from across government departments and governance levels, economic sectors and civil society to build a shared vision and ownership of an agenda for transformative change. It needs to bring to the table the diverse knowledge and expertise needed to collectively imagine, design and act towards agreed goals. There are diverse stakeholder groups with a potential to contribute to discussions and solutions to the marine pollution crisis, including industry, policy makers, civil society and academia (see Figure 9; see also UNEP 2016).

Figure 9. Examples of stakeholders relevant for 'A Plastic-Free Ocean' mission

Stakeholder type	Examples of relevant stakeholders
Industry, business and professional services	- Product designers; - Producers of plastic products; - Industrial users of plastic products; - Retailers; - Chemical industry; - Recycling industry; - Waste management sector; - Finance sector; - Users and providers of coastal tourism; - Shipping industry; - Fishing industry; - Aquaculture industry; - Port authorities.
Politicians and policy makers	- National and local politicians committed to the issue; - Representatives from across relevant ministries; - Different levels of governance.
Civil society	- Civil society organisations and movements; - Consumer organisations; - Artists; - Citizens (direct engagement).
Research	- Interdisciplinary representation of scientists and research organisations including natural sciences, engineering, social sciences and humanities.

The level and nature of engagement of various stakeholders in the process will depend on the overall ambition and design of the exercise. There are trade-offs between the depth and breadth of stakeholder representation in different phases of the process, which should be considered at the outset of the exercise. The decisions on stakeholder engagement will need to find a balance between inclusivity of participation and the disruptiveness of proposed innovations. The more transformative and radical innovations may require explicit decisions on who not to invite to take part in the process.

Given that most policy and regulatory power lies in the hands of national governments, the national level will remain a key level for designing and deploying some key regulatory and policy instruments. A significant degree of international collaboration and coordination, however, will be necessary to deal with the problem more effectively on the global level. Local and regional initiatives will be invaluable in mobilising local stakeholders to address specific problems related to marine plastic pollution.

One way of ensuring engagement across different levels of governance is to consider the mission-oriented policy roadmapping as a multi-level governance framework. The roadmapping process can include many initiatives implemented at different governance levels and, when needed, can cut across them and encourage collaborations between different levels and formal jurisdictions. The process should be based on a shared overall vision and targets, but should allow for a variety of solutions and local experimentations. Actors at different governance levels can play to their strengths and contribute specific inputs to the process.

6.3 Step 2. Baseline analysis

The baseline analysis aims to systematically review existing scientific evidence on the challenge underpinning the mission to order to map three interrelated landscapes:

- **Mission problematique:** Analyse the causal mechanisms and dynamics of impact pathways related to challenges underpinning a mission. Identify the root causes of the problem and list the primary impact hot spots. Map the SDGs onto the impact hot spots, indicating causal links with them and their key SDG targets.
- **Innovation landscape:** Identify and categorise existing and emerging innovations relevant for the mission, and relate them to the hot spots and the SDGs.
- **Policy landscape:** Identify and categorise the current policy mix and key non-governmental initiatives relevant for the mission, and relate them to the hot spots and the SDGs.

6.3.1 Mission problematique

Preparing the evidence base for the 'A Plastic-free Ocean' mission is highly challenging. There are significant uncertainties and knowledge gaps – or even 'deep ignorance' (Villarrubia-Gomez et al., 2017) – related to assessing impacts and selecting solutions for marine plastic pollution (Jambeck et al., 2015; Wang et al., 2017; Villarrubia-Gomez et al., 2017; Mendenhall, 2018). Wang et al. (2017) identified a 'gap in information needed to evaluate impacts of marine debris on coastal and marine species, habitats, economic health, human health and safety, and social values' in addition to a 'gap in capacity' in establishing the significance of the problem for global audiences. There are relatively few reliable measurements of waste generation, characterisation, collection and disposal, especially outside urban centres (Jambeck et al., 2015). There is limited evidence on the extent and distribution of sources, pathways and sinks, and the large-scale impacts on economies, ecosystems and human health of plastic pollution (Mendenhall, 2018). Scientific research about micro and nano-plastics is 'in its infancy' (Rochman et al., 2016).

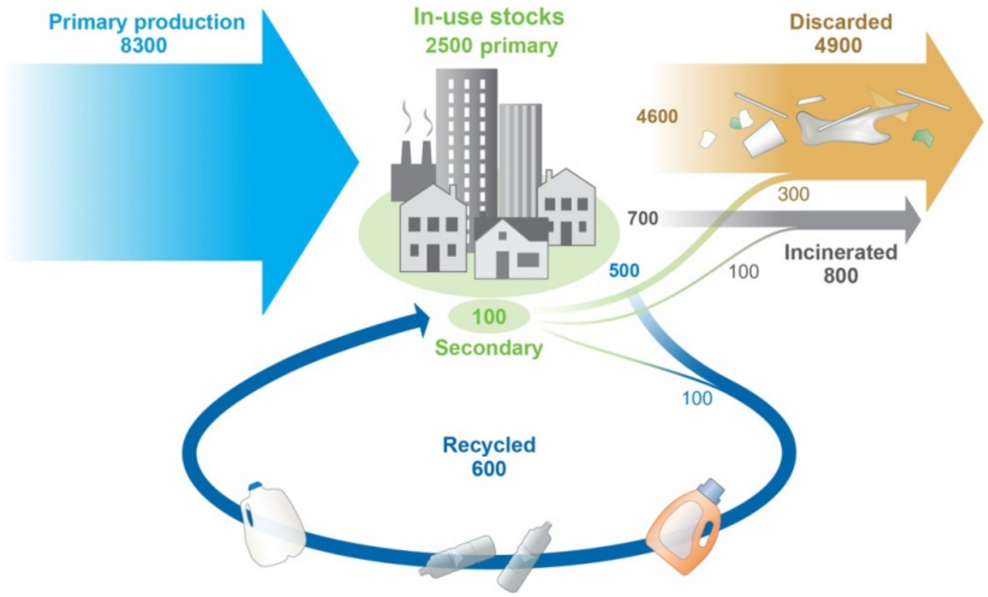
Given the uncertainty, it is key that the roadmapping process, including preparing the baseline for the process, engages scientists and experts who work on marine plastic pollution. This direct engagement is key for accessing the newest data and ensuring a balanced interpretation of the available evidence, including transparent assessment of confidence levels about major claims put forward by models and calculations. This can contribute to a research agenda which may accompany the mission-oriented policy roadmap. Despite significant gaps and uncertainties, the research so far appears to confirm marine plastic pollution as one the urgent environmental problems of today.

The scale and sources of the marine plastic pollution

The growth in plastics production after World War II surpassed production of any other man-made material: global production of resins and fibres increased from 2 Mt in 1950 to 380 Mt in 2015, a compound annual growth rate of 8.4% (Geyer et al., 2017). The vast majority of monomers used to make plastics, such as ethylene and propylene, are derived from fossil hydrocarbons. With oil prices relatively low, plastics have become relatively cheap. They can be highly durable: Geyer and colleagues (2017) estimated that about 30% of all plastics ever produced are still used. The durability of plastics explains both their success as a ubiquitous material and the challenge they pose to waste management and, once released, to the environment (Mendenhall, 2018).

Cumulative waste generation of plastic waste between 1950 and 2015 reached 6300 Mt. Only 9% (600 Mt) of this has been recycled and 12% (800 Mt) incinerated. **About 60% (4900 Mt) of all plastics ever produced have been deposited in landfills or in the natural environment** (Geyer et al., 2017; see also Figure 10). None of the commonly used plastics are biodegradable and they can dwell in the environment for hundreds of years. As a result, they accumulate, rather than decompose, in landfills and in the natural environment, including oceans.

Figure 10. Plastic material flows



Source: Geyer et al, 2017

Jambeck et al. (2015) calculated that about 275 million metric tons (MT) of plastic waste was generated in 192 coastal countries in 2010, of which **between 4.8 to 12.7 million MT of plastic waste entered the ocean in 2010 alone.** They warned that without improvements in waste management infrastructure and practices, the cumulative quantity of plastic waste which may enter the oceans from land may increase by an order of magnitude by 2025. The EU releases between 150,000 and 500,000 tonnes of plastic waste to the oceans every year (EC 2018), which affect vulnerable marine areas including the Mediterranean Sea and the Arctic Ocean (Werner et al., 2016).

Contrary to initial assumptions that the majority of plastic waste found in oceans comes from ship dumping, it is now clear that **marine plastic pollution originates mainly from land** (Jambeck et al., 2015; Vince and Stoett, 2018). The sources include wastewater outflows and storm water discharges, coastal recreation and tourism-related litter, waste released from dumpsites near rivers and sea coasts, accidental spills, illegal dumping and industrial activities (Mendenhall, 2018; EC 2018). Schmidt et al. (2017) estimated that rivers from 10 top-ranked catchments alone contribute between 88% and 94% of the total plastic debris. There is, however, no reliable data to support estimates of how much debris becomes immobilised in the sediment or on the banks of rivers, and how much gets carried out to sea.

The **ocean-based sources of marine plastic pollution** include shipping, fishing, aquaculture and other offshore economic activities. It is estimated that half of ocean-based plastic pollution comes from commercial fishing boats (Li et al., 2016). There is, however, no robust data or reliable global estimates of ship-based plastic pollution (Mendenhall, 2018).

In general, **the quantity of plastic waste entering the ocean depends on population size and the quality of waste management**. Studies conducted so far point to China and South-East Asian emerging economies as the main sources of mismanaged plastic waste entering oceans (Jambeck et al., 2015; see Figure 11). The estimates so far should be taken with caution. The study by Jambeck et al. (2015), the most often cited source of data on marine plastic pollution, has many caveats which the authors transparently admit. First, it focuses on waste from within 50 km of the coast and may, therefore, underestimate the load carried by rivers from inland sources (Mendenhall, 2018; see also Schmidt et al., 2017).

Furthermore, the estimates suffer from uncertainty related to limited data on waste generation, composition, collection and disposal outside urban areas, and do not account for illegal dumping or the import and export of waste internationally (Jambeck et al., 2015). The last point of uncertainty – the scale and composition of imports and exports of plastic waste – is highly relevant to establishing a better understanding of the problem, notably the role of the UK, the EU Member States and, more broadly, the Global North.

Figure 11. Global plastic waste generation in 2010

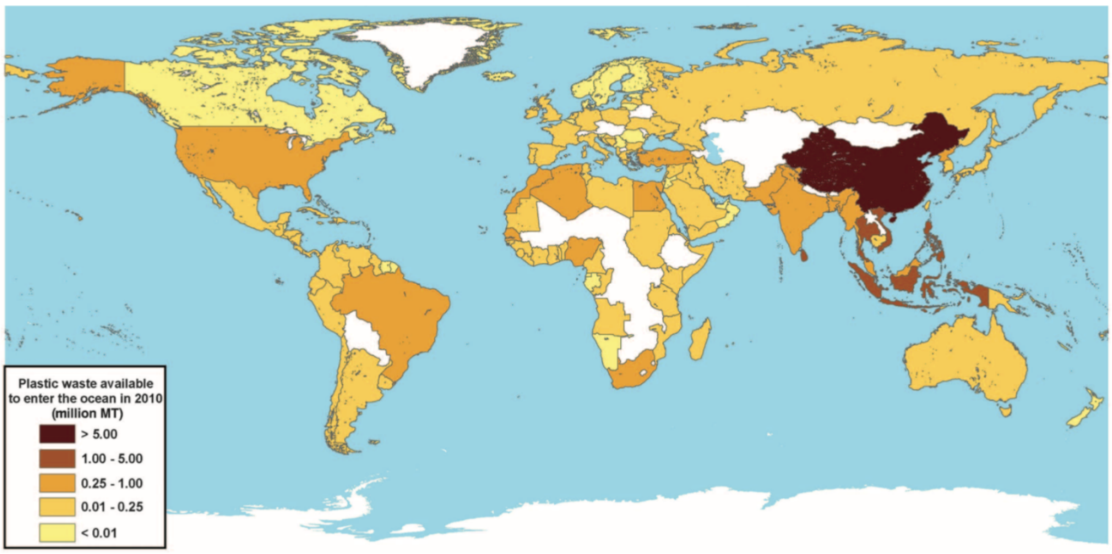


Fig. 1. Global map with each country shaded according to the estimated mass of mismanaged plastic waste [millions of metric tons (MT)] generated in 2010 by populations living within 50 km of the coast. We considered 192 countries. Countries not included in the study are shaded white.

Source: Jambeck et al, 2015

Composition and distribution

Plastic pollution is generally divided into three basic categories identified by size: macro-plastics, micro-plastics, and nano-plastics. Plastics of different sizes enter the environment by different pathways (see Figure 12). There are no reliable estimates of the amounts, density or distribution of micro- and nano-plastics in the ocean, the latter being least known. One estimate suggests that between 75 000 and 300 000 tonnes of micro-plastics are released into the environment each year in the EU (EC 2018). Despite uncertainties, it is clear, however, that micro- and nano-plastics exist throughout the ocean (Mendenhall, 2018). Plastic litter has been found in the most remote parts of the world's oceans and along the coastlines on all continents (Vince and Stoett, 2018).

Figure 12. Categorising plastic pollution

	Size	Possible sources and pathways
Macro-plastics	Items larger than 5 mm in diameter	Fishing nets, large pieces of Styrofoam, and plastic parcels that have been lost or discarded from cargo ships.
Micro-plastics	Particles under 5 mm in diameter (sometimes defined as less than 1 mm)	Include primary and secondary particles: plastic nurdles (used in various production processes) as well as fragments of larger plastic objects that enter marine ecosystems and degrade (e.g. often from cosmetics and personal hygiene, cleaning and medicine products). The water used to launder clothing made from synthetic fabrics is a significant source of microplastic fibres.
Nano-plastics	Particles under 200 nm (or less than 100 nm)	Include primary and secondary particles: originally manufactured nano-particles (e.g. nano-plastics used for agricultural or industrial uses, such as small-scale manufacturing using 3D printers) and nano-particles resulting from the end state of microplastic degradation (e.g. UV radiation, mechanical abrasion, 'biofouling', microbial colonization). Nano-plastics can pass through biological membranes impacting health of marine fauna and potentially humans.

Source: Based on Mendenhall, 2018

Plastic pollution does not diffuse evenly across the ocean and depends on the initial entry point to the ocean, air and water currents, and many other natural and anthropogenic factors (Wang et al., 2017). Marine plastic debris accumulates on the sea surface in five sub-tropical zones (or gyres): two in the Atlantic, two in the Pacific and one in the Indian Ocean. These zones emerge as a result of the complex interaction of the Earth's rotation and wind patterns. Other concentration areas include areas in the Bay of Bengal, South China Sea, and Gulf of Mexico, as well as the Arctic (Mendenhall, 2018). It may take up to two years for a piece of plastic debris to travel from a coastal zone to an oceanic gyre, but once it reaches the gyre it is unlikely to migrate elsewhere (Wang et al., 2017).

The garbage patches have attracted a lot attention, but do not represent the full scale of the problem. We know little about plastic pollution suspended in water, accumulated on the seafloor or washed out on beaches (Mendenhall, 2018). The significance of these gaps may be high: a couple of studies estimating the proportion of marine pollution deposited on the seafloor estimated that it may be between 50% to 70% of the total marine debris. Researching deep sea accumulation of plastic pollution, especially micro- and nano-particles, is highly challenging.

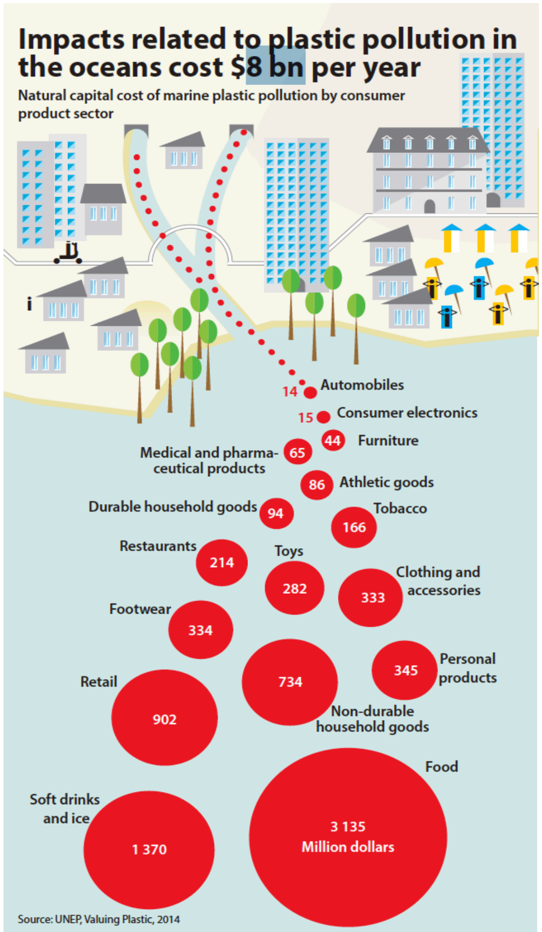
Key environmental and socio-economic impacts of the marine plastic pollution

Marine plastic pollution has significant environmental, social and economic impacts. The limited availability and quality of data influences the robustness of the existing impact assessment studies. The existing evidence, however, allows some relevant stylised facts to be put forward.

Concerning **environmental impacts**, the introduction of plastic pollution into marine environments disrupts the normal functioning of ecosystems, and has negative impacts on the health of marine fauna and flora. There is clear evidence of harm caused by marine litter to increasing numbers of species (Werner et al., 2016). Macro-plastics can entangle marine animals, and micro- and nano-plastics can be ingested at various trophic levels by animals that live both in water and on land, causing unnecessary suffering to marine animals (Werner et al., 2016; Mendenhall, 2018). There is evidence that plastic can transfer chemical contaminants to wildlife. However, there is considerable uncertainty about the relative importance of plastic as a pathway facilitating the transport of chemicals, compared to other pathways such as from water or natural diet (Werner et al.; 2016).

The presence of marine litter can modify natural habitats, and transport chemical contaminants and invasive species (Werner et al.; 2016). Plastics can damage coral reefs, which indirectly harms wider ecosystems that depend on them (Mendenhall, 2018). Estimating impacts on the level of entire ecosystems is highly challenging due to the limited quality and quantity of evidence, and the lack of baseline data. The existing studies focused mainly on single species, were conducted in laboratory settings and focused on sub-organism or organism level impacts (ibid). Despite the data challenges, it is clear that the relative importance of plastic as a solid environmental contaminant is likely to increase over time, among other reasons due to the abundance of plastics already in oceans (legacy items) which will continue to degrade and disintegrate (Werner et al., 2016).

Figure 13: Economic impacts of plastic pollution in oceans



Source: UNEP 2016.

Marine litter has negative **social and economic impacts**, including significant economic costs across consumer product sectors estimated at $8b per year (UNEP, 2016; see also Figure 13). In the EU, costs are estimated at €470m, with tourism and recreation, and fishing most affected. Economic damage from litter on the marine industry in the Asia Pacific region was estimated at $1.26n (EC 2018). The economic impact affects several economic sectors, including fisheries and aquaculture (e.g. damage to fishing vessels and equipment), tourism (e.g. impact on aesthetic value and attractiveness of beaches) and commercial shipping (e.g. damage to vessels and threat to human health) (UNEP, 2016).

Plastic pollution poses many potential health risks. Fishing nets and ropes pose a direct threat to human health and safety. Micro-plastics and nano-plastics are ingested by commercially important species of fish and shellfish which may pose health risks to humans. A range of potentially harmful chemical additives are present in plastic debris. Marine litter can be a vehicle for the transport of potentially harmful pathogens. At present, however, it is not certain if and to what extent human exposure to, or consumption of, these particles is harmful to health (Werner et al., 2016).

What does available evidence tell us about impact 'hot spots' for the mission?

The current plastic crisis is a legacy of decades of unsustainable production and consumption patterns, poor waste management practices and infrastructures, and insufficient regulatory and policy frameworks.

Despite significant gaps, there are several stylised facts which suggest areas which require intervention:

- **Scale**: The scale of the marine plastic pollution crisis is significant and likely to grow given the production trends and continuous degradation of legacy items in oceans.
- **Sources of plastic waste:** The great majority of plastic enters oceans from land, notably via rivers, but ocean sources are also a significant problem. We know a great deal about the geographical regions through which plastic waste enters oceans.
- **Composition:** We know little about the quantities and densities of micro- and nano-plastic waste in oceans, but they will continue to grow.
- **Pathways:** We know a great deal about where plastic waste concentrates on the ocean surface, but much less about plastics suspended in water or deposited on the seafloor. We know little about how plastics travel from where they enter the oceans to their destinations.
- **Impacts:** There are significant environmental and socio-economic impacts of marine plastic pollution. The environmental impacts should be considered in relation to other environmental impacts covering all key environmental SDGs (i.e. SDG 13: Climate Action, SDG 14: Life Below Water, SDG 15: Life on Land). The economic impacts include direct impacts on a number of sectors that depending on oceans (e.g. fisheries and aquaculture), as well as indirect impacts on virtually all consumer product sectors.

6.3.2 Innovation landscape

Mapping the innovation landscape aims to identify current and emerging innovations which can contribute to resolving the plastic crisis. The mapping should consider the scale, dynamics and urgency of identified sources and impacts. As a complex global challenge, marine plastic pollution requires a wide variety of innovations.

In preparation for a mission-oriented roadmapping, a comprehensive mapping of the innovation landscape relevant for marine plastic pollution should be conducted. Such a comprehensive horizon scanning should encompass existing and emerging innovations, ranging from technologically advanced solutions (e.g. material design) to grass-roots innovations (e.g. beach clean-up initiatives).

This horizon-scanning exercise can classify collected evidence on innovations as follows:

Type, novelty and maturity of innovation

- Type of innovation: product or service, process, marketing, organisational change, product-service system (business model), technical infrastructure, regulation and policy framework (including standards), governance mechanism.

Impact on material streams

- Key plastic streams affected, such as: PET (Polyethylene terephthalate), PVC (Polyvinyl chloride), HDPE (High-density polyethylene), LDPE (Low-density polyethylene), PP (Polypropylene), PS (Polystyrene).
- Impact on material streams: functional and material substitution, material efficiency.

Potential impact on the SDGs and SDG targets

- Nature of impacts:
  - Positive/negative impact;
  - Scale and likelihood of impact;
  - Impact over time (lead times to impact);
  - Geographical scope of impact;
  - Distributional impacts (including impacts on vulnerable groups).
- Impact on the SDGs and SDG targets:
  - SDG targets related to human health and wellbeing
  - SDG targets related to the economy and infrastructure (cross-sectoral impacts)
  - SDG targets related to the environment
  - Cross-cutting nexus impacts cutting across SDG clusters.

In order to organise horizon scanning, our suggestion is to distinguish between three innovation strategies targeting marine plastic pollution at different phases of the plastic material flow:

- **Upstream preventive strategy** eliminating or radically limiting the unnecessary use of plastics;
- **Downstream preventive strategy** decreasing the amount of plastic waste leakage to oceans;
- **Downstream curative strategy** addressing existing marine plastic pollution, notably innovative ways to collect, sort and treat marine plastic waste.

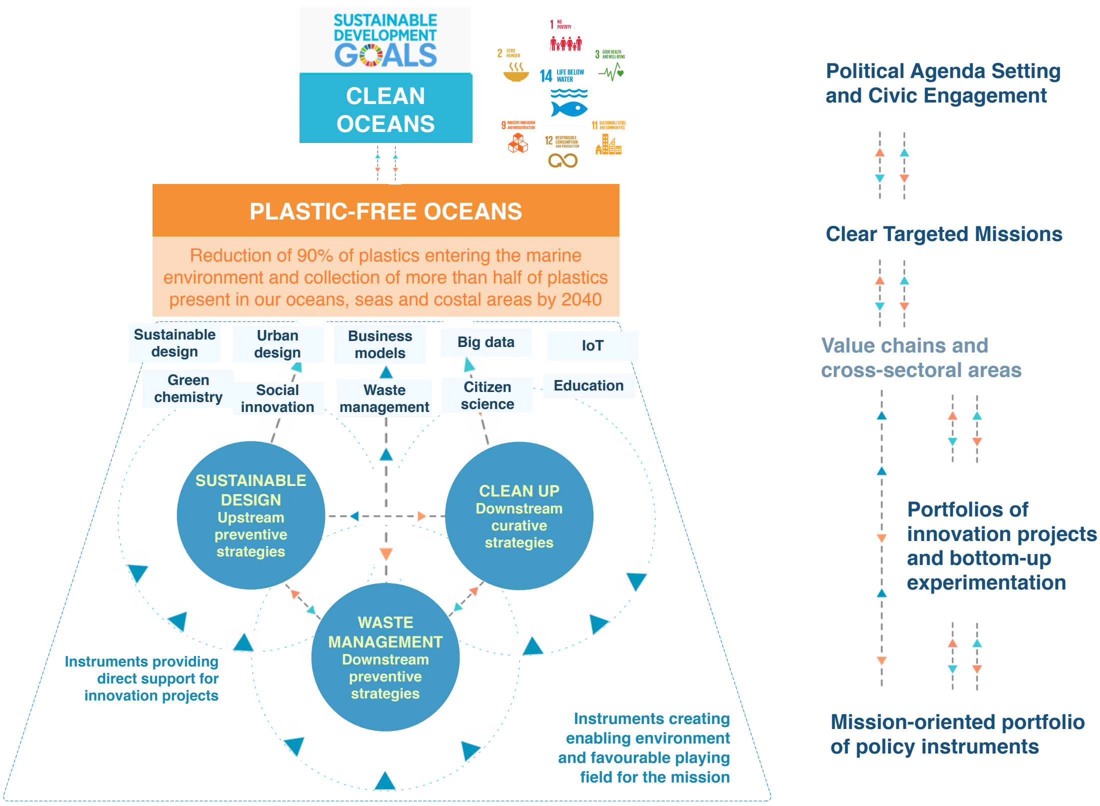
Upstream preventive approaches are innovations eliminating or radically limiting the unnecessary use of plastic products, components and packaging. This strategy includes various innovations, including functional and material substitution, innovative durable product design and new circular economy business models (e.g. remanufacturing), as well as social practices and behavioural changes altering current consumption patterns. The upstream preventive innovations are most likely to have transformative system-level impact on production and consumption patterns which underpin the marine plastic crisis. They are necessary to address the roots of the problem, but their impact on ocean pollution will likely be felt only in the longer term.

Current plastic consumption and production patterns, with plastic waste generated at the end of product life, are unlikely to be reversed in the short term. **Downstream preventive approaches** comprise innovations which prevent or radically decrease the amount of plastic waste leakage to oceans. This requires investments in innovative ways of collecting and managing waste, and re-using and recycling products and valuable materials at the end of their life. This strategy includes integrated waste management systems, infrastructures enabling material recycling and material recovery, as well as social practices and behavioural changes (e.g. re-use, waste segregation).

Finally, given the quantity and current impacts of plastic pollution already present in oceans, the mission needs to encompass innovative approaches to removing plastic debris from oceans to reduce negative impacts on the environment and economy. **Downstream curative approaches** encompass innovations addressing symptoms of the marine plastic pollution, notably innovative ways to collect and sort marine plastic waste, including collecting plastic waste floating on the water surface and suspended in the water column, as well as ways to minimise negative impacts of marine pollution on human life as well as on ecosystems.

Even if societies and economies should gradually move from downstream reactive approaches to upstream preventive approaches, the current level of plastic pollution requires all three innovation strategies to be pursued in parallel and will need to encompass a wide variety of innovations (see Figure 14). It is key to understand that these three innovation strategies will mobilise different stakeholders and innovation processes. They will have varying implications for different sectors, value chains and geographical spaces, and will require different resources and infrastructures. Stakeholders involved in the roadmapping process will discuss emerging innovations and the preparedness of innovation systems to accomplish the mission, and make suggestions for innovation strategies and project portfolios to focus on in Step 4 of the exercise.

Figure 14. Innovation pathways for 'A Plastic-Free Ocean' mission



Source: Authors.

6.3.3 Policy landscape

The problem of marine plastic pollution can be only addressed by multiple policy areas and numerous policy instruments. There is only limited evidence on how to design comprehensive policy portfolios to address the marine plastic crisis in the systemic way (Mendenhall, 2018). The pervasive and cross-cutting nature of the mission creates new opportunities and challenges for the design and coordination processes of mission-oriented policy portfolios. These portfolios will likely require new collaborations and governance mechanisms in order to ensure policy coherence and consistency.

Our suggestion is to map and review a comprehensive list of instruments with direct and indirect relevance for the marine plastic pollution (see Figure 5 and Annex II). This initial assessment could be conducted considering the potential contribution of the policy instruments in relation to the three innovation strategies identified above:

- **Instruments for upstream preventive approaches:** measures providing direct or indirect support to innovations radically limiting or substituting the unnecessary use of plastics;
- **Instruments for downstream preventive approaches:** measures providing direct or indirect support to innovations decreasing the amount of plastic waste leaking into oceans;
- **Instruments for downstream curative approaches:** instruments providing direct or indirect support to innovations addressing symptoms of marine plastic pollution, notably innovative ways to collect, sort and treat marine plastic waste.

A systemic overview of the policy landscape should encompass a comprehensive mix of instruments, and assess the relevance of the instruments for different phases of the innovation process and system (i.e. idea, R&D, design, demonstration, deployment, diffusion and systemic relevance for the innovation process; see Annex II). The latter will be crucial for developing a better understanding of the relative role of demand- and supply-side instruments for innovation, and will help to design portfolios, and sequence deployment and removal of policy instruments. By relating instruments to the types of innovation the analysis can indicate the potential sustainability impacts of entire policy portfolios on the SDGs, considering, for example, scale/likelihood of impact, lead time and geographical scope of impact.

6.4 Steps 3 to 6: Deliberative steps of the roadmapping process

Step 3: Specific goals and targets

With a broad baseline analysis in hand, stakeholders should deliberate a shared vision and overall objectives to guide the roadmap. The active participation of stakeholders is key for ensuring that final and interim targets and milestones are feasible and credible. The specific objectives, targets and milestones are likely to be adapted following elaboration of innovation pathways and policy portfolios.

Step 4: Innovation pathways

Step 4 develops and prioritises strategic innovation pathways and projects to be supported by the roadmap to deliver results in the short-, medium- and long-term. The scope and ambition of innovations supported by the roadmap will depend on the specific context in which the process is designed and implemented (e.g. political and business support). The nature of plastic pollution requires a variety of innovations providing responses to urgent problems and offering systemic alternatives. The roadmap is unlikely to address all the problems or cover all the possible actions.

Therefore, the process should prioritise pathways and innovations based on their impact on hot spots identified in baseline analysis. It is key that the choice of innovation mixes takes into account the potential of innovation systems and entrepreneurial eco-systems to enable the development and deployment of innovation. This includes systemic drivers (e.g. market demand), enabling factors (e.g. access to finance) and barriers (e.g. poor infrastructure) to research and innovation (R&I).

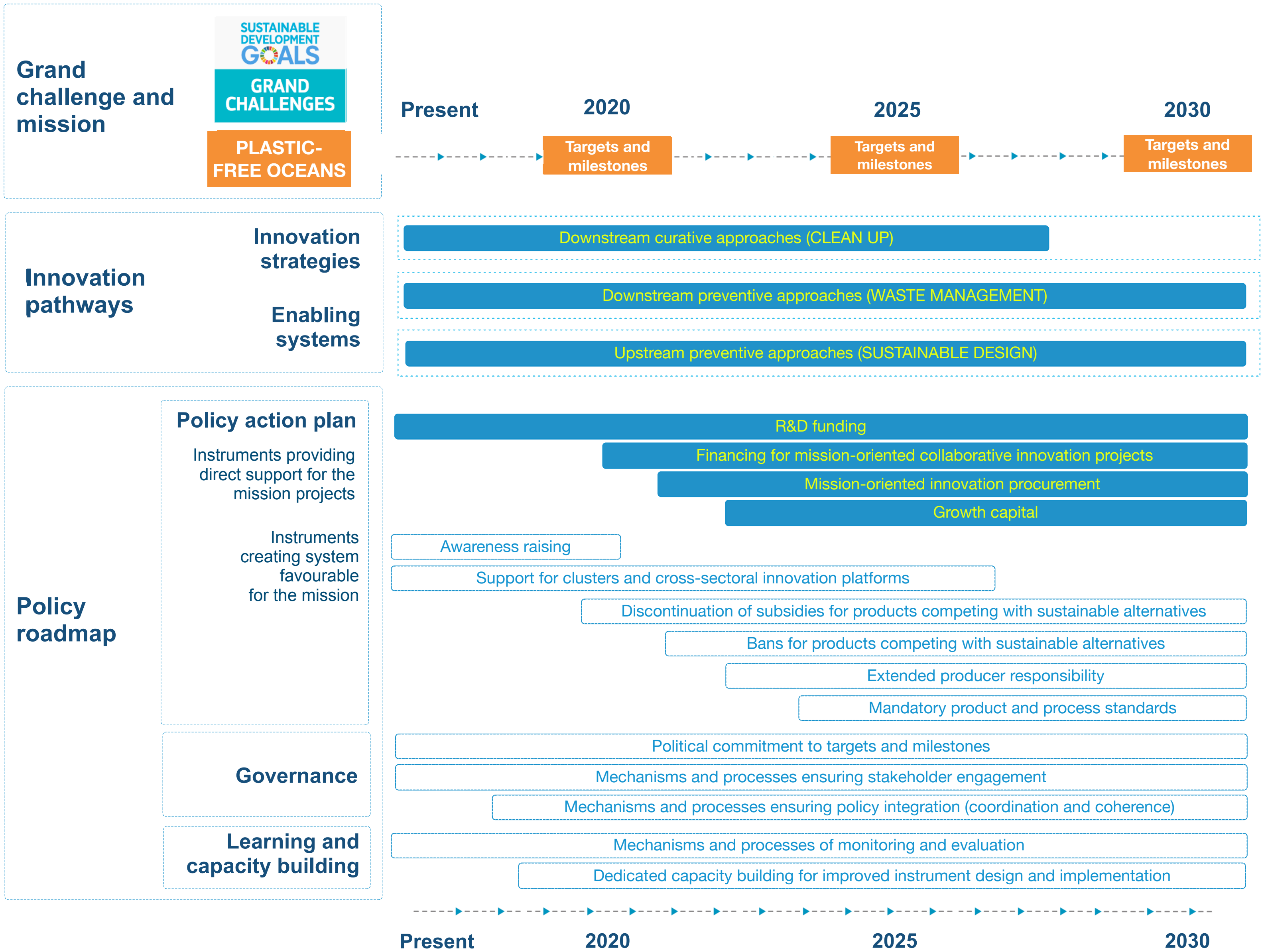
Step 5: Policy roadmap

Step 5 is devoted to designing a long-term policy roadmap with goals, targets and timelines of action (including instrument sequencing) to be introduced by public and private actors in the short, medium and long term. The roadmap should be accompanied by a short-term action plan introducing the governance and implementation process of the roadmap. Figure 15 is a tentative illustration of how the framework proposed in this paper can be used as a canvas to support the roadmapping process.

Step 6: Ongoing reflection and policy learning

Step 6 is key for ensuring continuous monitoring and evaluation, and ongoing reflection on the roadmap implementation. The roadmap should be seen as a learning process. As such it needs to be a policy learning environment where the progress and challenges encountered in the implementation process are discussed. It needs to be supported by capacity-building activities for all key stakeholders involved in the roadmap.

Figure 15. Mission-oriented innovation policy roadmapping framework for SDGs: A tentative macro-level policy roadmap for "A Plastic-Free Ocean" mission



7. Key messages

This paper proposes a mission-oriented innovation policy roadmapping framework as a systemic policy instrument – or a strategic framework for action – to give a long-term orientation to innovation support and ensure the coherence of an STI policy mix addressing high-impact missions for the SDGs. We argue that policy roadmaps have a potential to not only improve policy coherence, but also to create synergies between public and private initiatives to scale up investments and mobilise stakeholders around mission-oriented innovations.

Although this version of the framework is addressed mainly to national governments, the approach is also relevant for international organisations, and regional and local actors, as well as multi-stakeholder partnerships with the commitment, mandate and resources to pursue missions. Policy roadmaps should encompass a comprehensive policy mix with a variety of policy instruments. We argue that the mission-oriented policy roadmapping process could create new policy spaces for deliberating dedicated policy portfolios and adapting existing instruments to align them with the SDGs.

We strongly emphasise the role of deliberative governance and participatory processes underpinning policy roadmaps. Mission-oriented innovation roadmapping is a process engaging multiple stakeholders from different organisations, value chains and sectors. The participatory approach encourages a holistic perspective on challenges and opens up the process to a variety of innovation pathways relevant for the missions. The shared understanding of challenges and shared ownership of missions resulting from the participatory processes can improve implementation of innovation projects on the ground.

To encourage various stakeholders, our mission-oriented innovation policy framework rests on a broad understanding of innovation, and considers policy roadmapping an instrument encouraging learning, experimentation and demonstration of a variety of innovations and innovation pathways. With its timebound approach encompassing short-, medium- and long-term targets, roadmapping can comprise the deployment and diffusion of tested technologies offering 'quick wins', as well as 'patient investment' and experimentation with transformative system innovations promising benefits only in the longer term.

Crucially, there is a need for more international STI collaboration and coordination to address societal challenges more effectively and accomplish the SDGs. Mission-oriented policy roadmapping could become an approach to inspire and enable new forms of problem-based international collaboration and joint ventures on STI for the SDGs. The framework could also create mechanisms to connect and seek synergies between local and regional initiatives on the global level.

This paper offers a practical framework with concrete steps to guide design and implementation of mission-oriented innovation policy roadmaps. To illustrate how to apply the framework to a recognised complex challenge, we introduced background evidence and suggested how the framework could help to scope policy roadmapping for 'A Plastic-free Ocean' mission. Although incomplete, we hope this illustration is a useful contribution to policy processes related to many ongoing national and international initiatives addressing marine plastic pollution.

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Annex I. Steps in the mission-oriented innovation policy roadmapping for the SDGs

Step 1: Scoping: Identify a challenge and mission to be addressed by the roadmap

Objectives

- Agree on societal challenges and mission to be addressed by the roadmap.
- Relate the selected mission to the SDGs and the SDG targets.
- Engage key stakeholders committed to the mission.
- Secure necessary resources for the roadmapping process.
- Agree on the organisation and governance of the exercise.

Methods, processes and tools

- Desk research and scoping of the challenge and the mission.
- Map and analyse existing visions, goals, targets and commitments, including the SDGs, relevant for the challenge and the mission.
- Map and approach key actors relevant for accomplishing the mission.
- Preparatory meetings with stakeholders.

Outputs

- Short introductory document on the roadmap for larger audience.
- Methodological paper on the roadmap describing its objectives and process.

Step 2: Baseline: Conduct baseline analysis for the mission

Objectives

- Review existing scientific evidence on the selected problem.
- Create the impact map: Analyse the causal mechanisms and dynamics of impact pathways related to the addressed challenge; Identify the root causes of the problem and list the primary impact hot spots.
- Map the SDGs onto the impact hot spots: Map the SDGs and their key targets onto the impact map.
- Map the innovation landscape: Identify existing and emerging innovations relevant for the mission, and relate them to the 'hot spots', considering their maturity and feasibility of application.
- Policy landscape: Identify and categorise the current policy mix and private initiatives relevant for the mission, and relate them to the 'hot spots'.

Methods, processes and tools

- Desk research: scientific evidence and expert knowledge on the mission and discuss emerging research and innovation needs relevant for the mission.
- Horizon scanning: technological and non-technological innovations and initiatives relevant for the mission (indicate key innovations considering their maturity level).
- Innovation system analysis: Discuss the extent to which innovation systems, and socio-technical systems, enable or hamper innovations relevant for the mission.
- Policy mix analysis: analysis of the relevant policy mix on different governance levels
- Expert interviews and workshops.

Outputs

- Analytical report with baseline analysis.
- Summary report based on the baseline analysis.

Step 3: Vision and goals: Create a vision and set up goals and targets for the mission

Objectives

- Co-create a shared vision for the mission.
- Agree on the main objectives, targets and the time horizon for the roadmap, explicitly linking them to the impact hot spots.
- Agree on the interim objectives of the roadmapping process.

Methods, processes and tools

- Stakeholder and expert meetings
- Stakeholder and expert consultations (possibly including expert elicitation)
- Preparation of the internal management and communications strategy

Outputs

- Summary document highlighting the vision and objectives of the roadmap.
- Updated methodological report elaborating the roadmap's objectives and process, including on stakeholder participation.

Step 4: Innovation pathways: Select innovation pathways to accomplish the mission

Objectives

- Explore alternative innovation pathways for addressing the impact 'hot spots' and for accomplishing the mission.
- Identify the drivers, enabling factors and barriers of research and innovation (R&I), including market and system failures relevant for mission-oriented R&I.
- Choose the 'innovation mix' to be supported by the roadmap.
- Select portfolios of R&I projects (including experimentation and demonstration) to support the 'innovation mix' to achieve impacts on the targeted 'hot spots' in the short, medium and long term.
- Agree on expected timelines of implementation by indicating lead times to impact of research and innovation projects.

Methods, processes and tools (one or two stakeholder workshops)

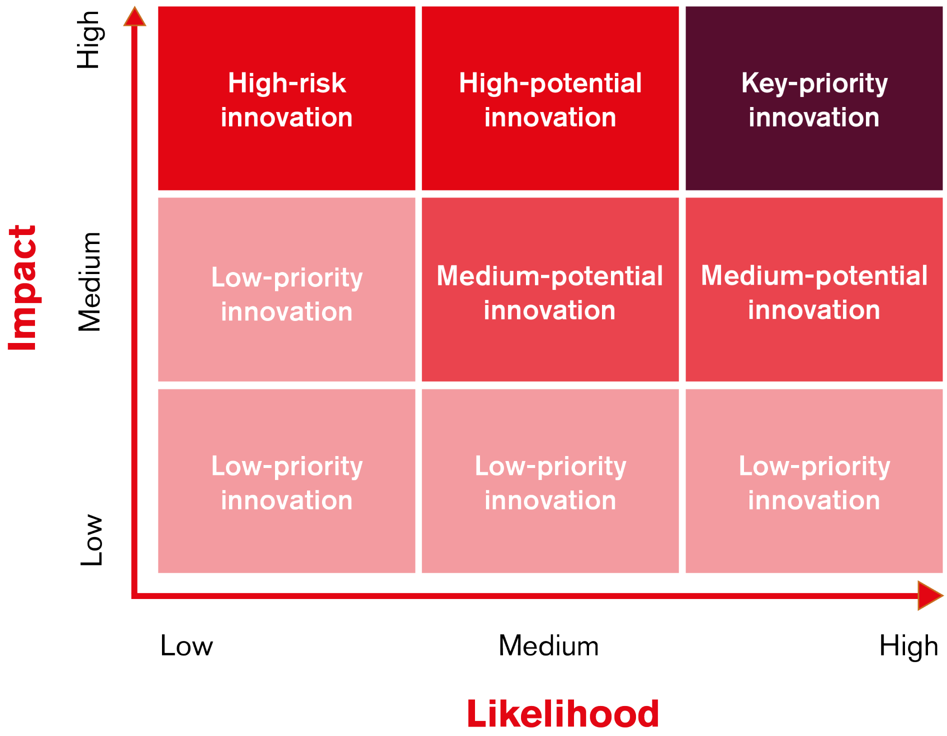
Workshop preparation

- Background materials rely on the desk research and interviews conducted during previous steps (see above).
- Workshop to engage representatives of various stakeholder groups.

Session 1. Mapping innovation landscape

- Participants list technological and non-technological innovation relevant for the mission, including system innovations. The maturity will be indicated on the innovation value chain (idea, R&D, design, demonstration, deployment, diffusion).
- They then assess the level and probability of the potential of innovations to accomplish the mission in the short, medium and long-term horizons. The session uses a probability-impact matrix (see Figure 16 below). The matrix is a reverse of a risk-impact matrix (Wilson 1998). It can be used to indicate the level of potential to accomplish mission targets (e.g. reduction of plastics entering the marine environment) and the probability of achieving an impact in a specific time horizon.
- The workshop participants map the innovation landscape using the impact-probability matrix for different time horizons: the short term (2020), the medium term (2025) and the long-term impact (2030). The same innovation may be inserted in different quadrants depending on the time horizon.

Figure 16. The impact-probability matrix applied to innovation mapping



- Introduction of the timeline allows for the considerations of innovations at different levels of maturity which may become impactful at different times (e.g. innovation in development may become highly relevant in 2030).
- Following the mapping the selected most impactful innovations are mapped onto the timeline where the x-axis is a timeline (now to 2030 or beyond) and the y-axis is impact (medium and high). Individual innovations are given tags indicating the likelihood of achieving the impact (i.e. low, medium, high).
- The ensuing picture is the basis for the discussion on barriers and drivers to the selected innovations.

Session 2. Mapping barriers and drivers to the selected innovations

- Participants reflect on barriers and drivers to innovation in the short, medium and long term focusing on the high-impact innovations identified in the previous session (top cells of matrices).
- The session uses the STEEP technique to differentiate between different types of barriers and drivers, and between local and global trends (see Figure 17 below). The main focus is on indicating the role of policy instruments as drivers and barriers of innovation.

Figure 17. STEEP mapping of barriers and drivers

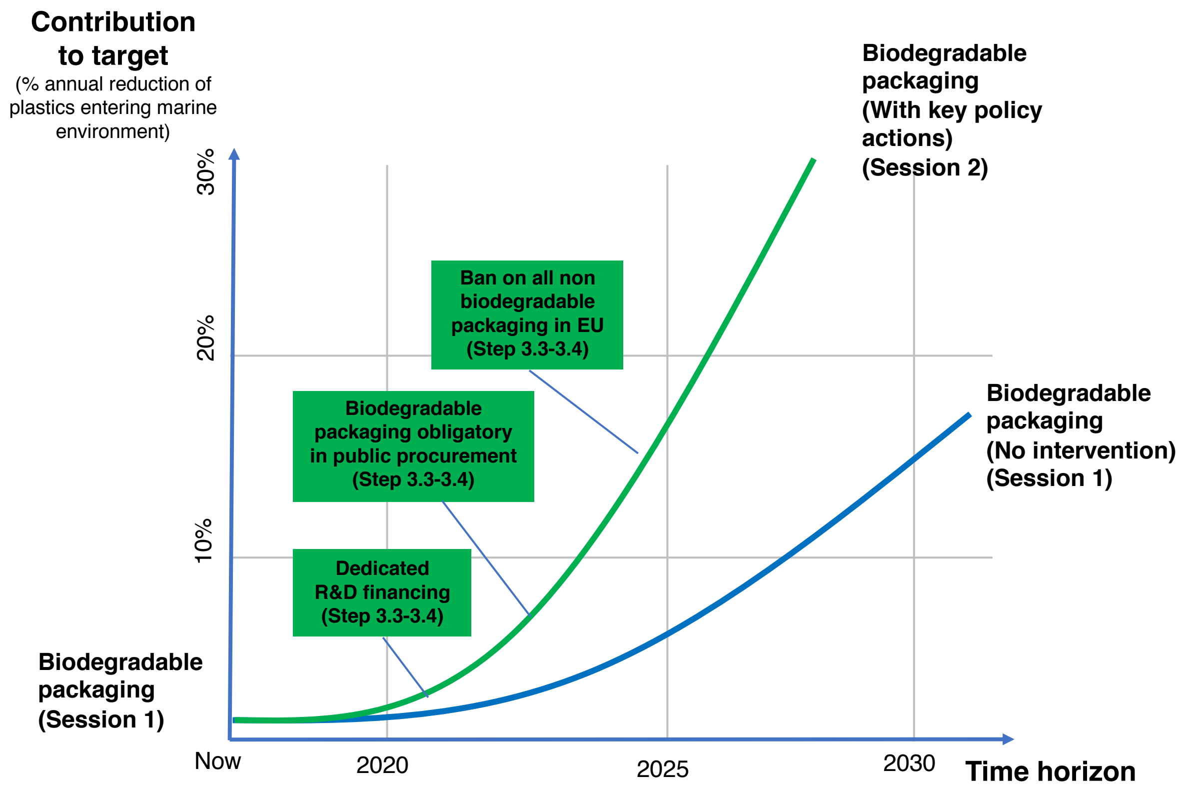
STEEP factors	Barriers		Drivers		Key actions to strengthen the enabling system
	Local	Global	Local	Global	
Social and cultural					
Technical and technological					
Economic and financial					
Environmental					
Political and policy					

- Participants agree on the most relevant determinants and suggest policy instruments or portfolios to provide direct (e.g. public procurement) or indirect support (e.g. bans) to innovation in short, medium and long term. The exercise should prioritise actions that stakeholders involved in the roadmapping exercise can commit to and implement.
- Participants reflect about the extent to which policy actions can lower the risk of high-impact innovations (i.e. increase likelihood of impact) and whether lead times to impact can be reduced due to policy interventions. These assumptions are expert-based estimates.
- The appraisal of barriers and drivers allows a reassessment of the innovation landscape created in Session 1. Annotations are added to innovations indicating the key barriers and actions which can increase probability and reduce lead times to impact.
- This is the basis for a deeper reflection on innovation pathways which takes into account policy intervention (e.g. assuming policy intervention some innovations initially classified as high risk may be reclassified as lower risk and/or may reach their highest impact at different time).

Session 3. Innovation pathways

- Based on the previous session participants sketch impact pathways of innovations expected to have highest impact at different points in time.
- The reflection on barriers, drivers and risks associated with the key innovations, allows for the construction of innovation pathways, and for the reflection about their likely impacts, with and without implementing policy instruments and portfolios (see Figure 18 for an illustration).

Figure 18. Possible depiction of innovation pathways



Session 4. Innovation portfolios

- Participants suggest alternative portfolios of innovations with the highest impact on accomplishing the mission. The purpose is to co-design the 'innovation mix' comprising innovations with the highest expected impact potentials at different points in time.
- This should be based on the assessment of the cumulative impact of selected innovations at different points in time. The challenge is to consider interdependencies between different innovations over time.
- Key is finding a balance between innovations delivering short-term and long-term impacts, and between innovations addressing the roots of the problem (e.g. systemic substitutions, behavioural changes) and innovations treating symptoms (e.g. collection and recycling of plastic waste).
- Participants conduct the preliminary assessment of costs, efforts and capabilities required by different innovation portfolios.
- Based on the above assessment participants select the innovation portfolio (or portfolios) to be supported by the policy roadmap.

Step 5. Policy roadmap: Co-design a mission-oriented policy roadmap

Objectives

- Explore key policy instruments and policy portfolios to provide direct and indirect support to the selected innovations.
- Co-design a long-term policy roadmap with goals, targets and timelines of action (including instrument sequencing) led by public and private actors in the short, medium and long term.
- Assign short and medium-term actions to stakeholders, notably on experimentation and demonstration projects for the mission.
- Agree on indicators for monitoring and evaluation of the roadmap.
- Prepare a short-term policy action plan introducing the governance and implementation process of the roadmap.

Methods, processes and tools (two stakeholder workshops)

Workshop preparation

- Based on the desk research and interviews conducted in the previous steps, notably mapping policy instruments, policy strategies, objectives and targets, and mapping governance mechanisms and key stakeholders
- For the workshop use, the roadmap canvas should be printed in a large-scale format and come with pre-prepared icons and shapes.
- Mission objectives, targets and the innovation portfolio agreed during previous sessions should be visualised on the canvas.

First workshop – Co-designing a mission-oriented policy portfolio

Session 1. Introduction of the selected innovation portfolios

- Presentations of innovation pathways with key drivers and policy instruments (based on Step 4 and complemented with desk research)

Session 2. Assessing relevance of policy instruments for key innovations

- Identifying policy instruments with a potential to contribute to the innovation value chain of selected innovations (see Annex II)

Session 3. Co-designing a policy portfolio for the selected innovation

- Identification of key policy instruments to support innovations at different times (e.g. short-, medium- and long-term needs)
- Identification of relations between instruments (e.g. synergy, dependence)
- Assessment of policy capacity to design and implement policy instruments
- Co-designing timebound policy portfolios based on capacity assessment and including actions to improve capacity (see Annex III)

Session 4. Key actions for the roadmap's action plan

- Preliminary list of instruments and actions that the roadmap partnership can take in short term
- Identification of key target groups with capacity to take further action in the short term (e.g. finance)
- Suggestions for high-level policy recommendations.
- Interlude between the workshops
- Preliminary negotiations and commitments agreed by stakeholders (or stakeholder partnerships) on actions which they can take to contribute to the implementation of the roadmap
- Preliminary commitments on the governance and leadership of the roadmap
- Preparation of the draft action plan for comments

Second workshop – Mission governance and the policy action plan

Session 1. Key actions for the policy action plan

- Agree on concrete activities, objectives and milestones directly linked to the desired innovation pathway
- Agree on how to measure progress towards accomplishing the mission

Session 2. Governance structure and implementation

- Agree on the governance structure and modes of implementation
- Agree on a monitoring and evaluation process
- Session 3. Memorandum of understanding
- Launch of the roadmap

Outputs

- Document comprising baseline analysis, innovation pathways and policy roadmap
- Stand-alone policy action plan and policy learning plan.

Step 6: Policy learning: Ensure ongoing reflection and action learning

Objectives

- Build a policy learning environment supporting the implementation and ongoing reflection on the roadmap.
- Establish dedicated capacity building processes and design a learning environment for stakeholders involved in the roadmap.

Activities

- Assess institutional capacity to design, implement and evaluate policy actions.

Outputs and outcomes

- Established governance structure for the roadmap (e.g. committee, commission)
- Established and appropriated metrics of the roadmap.
- Dedicated budgets and actions to support the roadmap from the key stakeholders.

Annex II. Mapping policy instruments with additionality potential for mission-oriented innovation portfolios

Category		Innovation portfolio [Descriptive name here]	Idea	R&D	Design	Demonstration	Deployment	Diffusion	Systemic
	Instrument	Describe transformative potential of instrument	Rate relevance of the instrument for innovation process (3-step scale where 1 is highest relevance). Leave fields blank if instruments are not relevant for the innovation process.						
Direct financial support for innovation									
	Institutional funding for public research organisations (universities & PRIs)								
	Project grants for public research organisations								
	Grants for business R&D and innovation								
	Centres of excellence grants								
	Procurement programmes for R&D on eco-innovation								
	Fellowships and postgraduate loans and scholarships								
	Loans and credits for innovation in firms								
	Public finance								
	Feed-in Tariffs								
	Equity financing								
	Innovation vouchers								
Indirect financial support									
	Corporate tax relief for R&D and innovation								
	Tax relief for households for R&D or adoption of eco-innovation								
	Debt guarantees and risk sharing schemes								
	Taxation of environmentally-harmful technologies								

Category		Innovation portfolio [Descriptive name here]	Idea	R&D	Design	Demonstration	Deployment	Diffusion	Systemic
Technology guidance and business advisory services									
	Technology transfer and business advisory services								
	Business incubation advice								
Collaborative platforms and infrastructure									
	Clusters and other networking and collaborative platforms								
	Dedicated support to new research infrastructure								
	Information services and databases								
Governance and regulatory framework									
	National strategies, agendas and plans								
	Policy roadmaps and long-term action plans								
	Creation or reform of governance structures or public bodies								
	Policy intelligence (e.g. evaluations, forecasts)								
	Formal consultation of stakeholders or experts								
	Horizontal STI coordination bodies								
	Product and process standards and certification								
	Labour mobility regulation and incentives								
	Intellectual property regulation and incentives								
	Public awareness campaigns and other outreach activities								
	Science and innovation challenges, prizes and awards								

Annex III. Designing a mission-oriented innovation policy portfolio

Category		Innovation portfolio [Descriptive name here]	Current	2020	2025	2030
	Instrument	Existing institutional and political capacity to design and implement an instrument	Indicate timeline of an instrument (decision, design, start and, where relevant, end of public intervention) (Where relevant) indicate time needed to build necessary capacity to design and effectively implement instruments; Indicate relations with other instruments by drawing critical paths (dependence, synergy)			
Direct financial support for innovation						
	Institutional funding for public research organisations (universities & PRIs)					
	Project grants for public research organisations					
	Grants for business R&D and innovation					
	Centres of excellence grants					
	Procurement programmes for R&D on eco-innovation					
	Fellowships and postgraduate loans and scholarships					
	Loans and credits for innovation in firms					
	Public finance					
	Feed-in Tariffs					
	Equity financing					
	Innovation vouchers					
Indirect financial support						
	Corporate tax relief for R&D and innovation					
	Tax relief for households for R&D or adoption of eco-innovation					
	Debt guarantees and risk sharing schemes					
	Taxation of environmentally-harmful technologies					

Category		Innovation portfolio [Descriptive name here]	Current	2020	2025	2030
Technology guidance and business advisory services						
	Technology transfer and business advisory services					
	Business incubation advice					
Collaborative platforms and infrastructure						
	Clusters and other networking and collaborative platforms					
	Dedicated support to new research infrastructure					
	Information services and databases					
Governance and regulatory framework						
	National strategies, agendas and plans					
	Policy roadmaps and long-term action plans					
	Creation or reform of governance structures or public bodies					
	Policy intelligence (e.g. evaluations, forecasts)					
	Formal consultation of stakeholders or experts					
	Horizontal STI coordination bodies					
	Product and process standards and certification					
	Labour mobility regulation and incentives					
	Intellectual property regulation and incentives					
	Public awareness campaigns and other outreach activities					
	Science and innovation challenges, prizes and awards					

Annex IV. Mission-oriented innovation policy roadmapping canvas

		Where are we?		How are we going to get there?			What do we want to achieve?
VISION		**Past**	**Now**	**Short-term (2020)**	**Medium-term (2025)**	**Long-term (2030 and beyond)**	**Long-term objectives and targets**
GRAND CHALLENGE AND MISSION	Grand challenge						
	Missions						
INNOVATION PATHWAYS	Key innovations						
	Enabling systems						
POLICY ROADMAP	Policy action plan						
	Governance						
	Learning and capacity building						

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