A framework for mission-oriented innovation policy: Alternative pathways through the problem-solution space

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ABSTRACT: We aim for a better conceptualization of Mission-oriented Innovation Policy (MIP). Our starting point is an analytical decomposition of societal problems and innovative solutions based on the degrees of wickedness regarding three aspects: i) contestation, ii) complexity and iii) uncertainty. We argue that both problems and solutions can be diverging (contested, complex, uncertain) or converging (uncontested, well-defined, informed). Based on the resulting problem-solution topology, we suggest a process-oriented view on MIP and discuss three alternative pathways along which convergence between problems and solutions can be achieved to transform wicked problems into legitimate solutions. We illustrate the pathways with the examples of smoking bans, CCTV and wind energy. For policy makers, locating a societal challenge in this problem-solution space, and implementing policy strategies accordingly, is expected to accelerate both the legitimacy of a mission and the resulting solutions.

Keywords: innovation policy, wicked problems, mission, societal challenges, grand challenges
1. Introduction

In the wake of societal challenges facing countries around the world, innovation policy is undergoing major changes. No longer is economic growth the sole guiding rationale for stimulating technological development. Instead, there is an emerging consensus that innovation, and innovation policy, should focus on solving concrete and pressing problems in society at large.

The change in the objectives of innovation policy from economic growth towards societal challenges has prompted renewed interest into mission-oriented types of innovation policy (MIP) that were particularly prevalent in the 1960s and 1970s. However, the meaning of MIP today differs considerably from its meaning in the past. Past policies used to be framed in terms of ambitious technical achievements with the man-on-the-moon project as the archetypical example of a technology-led mission (Nelson 1974). With a clear formulation of the problem and the solution, these missions addressed a relatively ‘tame’ problem, but paid scant regard to societal or economic impacts (Mowery et al. 2010). By contrast, over the past decade, missions have been directed to the persistent societal problems of our time, also labelled as ‘grand challenges’ or ‘societal challenges’, such as climate change, ageing, and security (EC 2011; Cagnin et al. 2012; Hicks 2016; Mazzucato 2018a).

Compared to traditional technology-led missions, societal challenge-led missions appear more complex and unstructured, going beyond technological advances alone. It is the ‘wicked’ nature of societal problems (Rittel and Webber 1973) that poses new questions and obstacles for innovation policy makers. Pursuing a societal mission-oriented approach raises the issue of how to identify, define and subsequently target a problem which is complex and systemic and for which solutions, be it a technological or non-technological solution, can be hardly predefined.

In this view, mission-oriented innovation policy relates to policies supporting transformative system change (Weber and Rohracher 2012; Rogge and Reichardt 2016; Schot and Steinmueller 2016; Boon and Edler 2018). Societal challenges may require fundamental societal transformations, not just technologically but also institutionally and behaviorally, as recognized in the literature on socio-technical transitions (Geels 2004; Smith and Kern 2009; Alkemade et al. 2011). Indeed, the persistent nature of societal problems may call for missions that go beyond the optimization of current socio-technical systems. In this context, Weber and Rohracher (2012) suggested that the rationales for challenge-led innovation policies follow from ‘transformational’ system failures, including the lack of directionality, the lack of demand articulation, limited reflexivity and missing coordination across policy domains and levels. Accordingly, a major part of mission-oriented innovation policy lies in ensuring legitimacy, broad engagement and cooperation among multiple actors to govern the wicked challenges of current societies (Borrás and Edler 2014; Kuhlmann and Rip 2018; Schot and Steinmueller 2018).

As yet, the literature on MIP has remained relatively silent on the fact that societal challenges may fundamentally differ in nature. Different societal problems may require different types of solutions, and consequently, different types of policies to address a societal challenge effectively. Both academics and policy makers have focused primarily on the range of technological solutions conceivable to solve a societal problem (Diercks et al. 2018). In doing so, the framing and legitimacy of a societal challenge itself has been often taken for granted, just as the need for technological innovation. While some challenges may indeed require research and innovation or fundamental transitions in the socio-technical
regimes that society employs, other problems may be tackled by regulation and behavioral change (institutional innovations) without necessitating technological innovation per se. Hence, MIP goes beyond the spheres of science or innovation policies alone (Kuhlmann and Rip 2014), which implies that alternative policies, or policy mixes, to tackle societal challenges should not be disregarded.

We will argue that societal challenges, and the corresponding innovation missions, may differ in many ways. Drawing on policy sciences, there is much more to say about the complexity and scope of societal challenges, beyond their generic definition as ‘wicked’ (Rittel and Webber 1973; Levin et al. 2012; Newman and Head 2017; Daviter 2017). The simple wicked-tame dichotomy often invoked does not do justice to the heterogeneity of the underlying problem structures, nor to the specific design of missions needed to tackle them. Here, the policy sciences literature proves useful to take into account the value-based discourses in formulating a challenge and to capture the political dynamics in framing ‘the best’ solutions for a particular problem (Hoppe 2011; Ison et al. 2015). By disregarding the ‘degree of wickedness’ involved in a particular challenge, the innovation policy literature runs the risk of providing a one-size-fits-all approach for a MIP, with taken-for-granted problem definitions and a too strong emphasis on technological innovation, while marginalizing the opposing voices and discarding complex trade-offs. As a consequence, MIP as currently conceived may turn out to be much less effective than many hope for.

Below, we combine insights from innovation studies and policy sciences to provide analytical clarity about the nature of a particular societal challenge on the one hand, and the differences in scope and scale between different challenges on the other hand. We will distinguish between two analytical dimensions referring to the problem side (i.e. the type of underlying problem structures) and the solution side (i.e. the type and availability of potential innovations) of a societal challenge. From this, we derive a two-dimensional problem-solution space which allows one to locate different societal challenges depending on their divergence or convergence of both problems and solutions.

On this basis, we argue that a MIP should be seen as a policy that provides directionality in supporting the process towards converging problem-solution constellations. In this way, it aims at advancing problem-solution constellations which become sufficiently stable to serve as common frame of reference for actors. If such a configuration emerges, a mission-oriented approach can provide guidance to the conventional market-based or system-based innovation policies to support the upscaling and diffusion of technological and/or institutional innovations.

The remainder of this paper is structured as follows: In Section 2 we briefly review the literature with respect to the development of MIP. Section 3 provides the analytical basis for decomposing societal challenges in problem side (Section 3.1) and solution side (Section 3.2) of diverging/converging societal problems and innovative solutions, while Section 4 introduces four different problem-solution constellations. In Section 5 we discuss three stylized policy pathways to achieve convergence around societal problems and solutions, and derive implications for a further theoretical conceptualization and practical implementation of MIP in Europe. Section 5 concludes with further research needs on MIP.
2. The re-emerging interest in mission-oriented innovation policies

Mission-oriented policies originally emerged as a technology policy concept implemented to support governmental goals of national importance. Often recalled historical examples of science- or technology-led missions are the Manhattan project, or the U.S. Apollo project putting a man on the moon (Hicks 2016; Mazzucato 2017; Kaldewey 2018). This classical mission-orientation was motivated primarily by political ambitions more than economic competitiveness. The technology missions in the 1970s and 1980s stand in contrast to diffusion-oriented policy approaches adopted by countries such as Germany or Sweden focusing predominantly on the diffusion of technological capabilities (Ergas 1987; Cantner and Pyka 2001).

It was only in the 1970s that technology-led missions for economic purposes started to dominate as a response to the economic downturn. As a result, mission-oriented programs increasingly pursued industrial policy ambitions. Among the best known examples of a mission that was driven by both industrial and political ambitions was France’s high speed train TGV. However, with the limited success of government-led missions to deliver economic growth and employment, the mission-oriented approach became increasingly discredited. Instead, since the 1990s, innovation policy was dominated by a belief in generic technology-neutral policies fixing market and system failures as to improve a nation’s innovation and growth performance without the directionality provided by mission-oriented policies in the past (Boekholt 2010; Mazzucato 2017).

During the last decade, academic interest in mission-oriented approaches has attained renewal due to growing concerns about threats posed by global warming. A belief that a “strong, well-resourced government technology policy is part of the solution [for climate change]” (Mowery et al. 2010, p. 1012) has fuelled the academic discourse on innovation policy targets related to future needs of society rather than generic innovation objectives. Early contributions by Mowery et al. (2010) and Foray et al. (2012) emphasized the ways in which societal challenge-oriented missions differ from traditional technology-oriented missions: Societal missions (i) show longer time frames and are of greater breadth, (ii) make (technological) diffusion inevitable as neither the state nor any other actor will be the single user of the innovation, (iii) require a diversity of funding and investment sources and coordination between numerous actors, and (iv) often have to overcome established industrial structures dominated by incumbents with which new solutions have to compete (Foray et al. 2012, p. 1698). What is more, a stronger need for demand-side policies and policies targeted at behavioural change was identified (Mowery et al. 2010; Foray et al. 2012).

More recently, a wider literature stream emerged under the labels of ‘innovation policy for grand challenges’ (Ulnicane 2016; Frenken 2017; Edler and Boon 2018; Kuhlmann and Rip 2018), ‘new mission-oriented policy’ (Mazzucato 2017, 2018a) or ‘transformative innovation policy’ (Steward 2012; Diercks et al. 2018; Schot and Steinmueller 2018). Despite some differences in emphasis and labelling we can identify a set of defining characteristics broadly shared between these approaches.

First, challenge-oriented innovation policies are directed towards complex, multi-dimensional and systemic societal problems. Importantly, many societal challenges are open-ended in nature without the expectation that the underlying problems can be fully solved (Kuhlmann and Rip 2014). The complex and open-ended nature of societal challenges may impede the articulation of clear-cut missions and bears the risk of arriving at missions without a clear target. As a way to address the multi-dimensionality
of societal challenges, Mazzucato (2018b) proposes to define of a set of clear research and innovation mission projects at the European level, all derived from the broader challenge. Her approach thus assumes that complex societal problems can be decomposed into more manageable building blocks with clearly defined targets. The transformational innovation policy approach of Schot and Steinmueller (2018) instead takes a different, more radical, position in regarding the systemic nature as inherent to today’s societal problems. They call for experimenting with fundamentally different policy models and the development of new experiences to foster socio-technical system change.

Second, the role of innovation policy genuinely changes in a mission-oriented context. While conventional innovation policies were mostly ‘neutral’ with regard to the innovation output, the legitimization of policy intervention shifted. With the advent of transformational policy, supporting ‘directionality’, ‘coordination’, ‘reflexivity’ and ‘demand articulation’ (Weber and Rohracher 2012) emerged as new reference points for innovation policy. Recently, the role of innovation policy is increasingly seen in shaping the direction of innovation activities (Mazzucato 2013, 2016), in formulating societal needs and their articulation into demand (Boon and Edler 2018), and in breaking-up of path-dependencies in the existing system (Schot and Steinmueller 2018).

Third, new mission-oriented approaches call for new and more decentralized governance modes. With societal needs being a central innovation policy objective there is an enlarged set and variety of stakeholders influencing and being influenced by the policy agendas (Borrás and Edler 2014; Kuhlmann and Rip 2018). More inclusive arrangements go beyond well-established innovation systems built around incumbent firms, but involve consumers, professionals, NGOs and lower governments (Frenken 2017). A mission formulation is increasingly recognized as a political process involving a plurality of actors and governance structures that are capable of dealing with conflicts emerging along core values of societal actors (Steward 2012; Kuhlman and Rip 2018). Broad societal acceptance and legitimacy of the defined challenge is regarded essential to generate the demand needed for societal diffusion (Edler and Boon 2018).

3. Contextualizing societal challenges: Beyond a wicked problem framing

Despite progress in conceptualizing the new roles and governance modes necessary to deal with societal problems in the sense of a MIP, the innovation policy literature lacks approaches that can cope with the heterogeneity of societal challenges at hand. Challenges may be wicked in different ways and to different degrees. They vary considerably in the scale and scope of the underlying problem statements on the one hand, and the scale and scope of solutions that are regarded as feasible and legitimate to tackle the problem on the other hand. Conceptually disentangling societal challenges by their problem and solution structures may prove particularly useful if we assume that technological innovations may indeed be key but not necessarily silver bullets in tackling current challenges.
3.1. The problem side: Diverging or converging problem statements

Wicked problems are societal problems that are complex, unpredictable, and have poorly defined boundaries, while so-called tame problems are inherently different by resembling more typical scientific and technical problems (Rittel and Webber 1973). As pointed out by Newman and Head (2017), fully tamed scientific or technical-type problems usually do not reflect the policy realities for societal issues. Most of the recent societal problems have highly wicked tendencies and are “immune to linear, rational or scientific methods of problem-solving” (Newman and Head 2017, p. 414).

Several policy sciences scholars have attempted to determine the ‘wickedness’ of policy issues and problem structures (Roberts 2000; Head 2008; Hoppe 2011; May et al. 2013; Alford and Head 2017; Carley and Christie 2017). Accordingly, the degree of wickedness can be seen as combination of different dimensions (Head 2008). Reoccurring aspects in the scientific discussion and topologies of wicked problems are:

(i) **contestation** referring to the degree of normativity related to an issue. Contestation is seen as the result of diverging claims, values and framings, or the inherent conflicts of interest resulting from social pluralism and stakeholder divergence (Hoppe 2011; Alford and Head 2017);

(ii) **complexity** understood in institutional terms is caused by the multi-scalar and multidimensional nature of societal problem (May et al. 2013; Carley and Christie 2017). Responsibilities for action or non-action are hard to determine, causing a ‘problem of many hands’ (Thompson 1980) especially if multiple actors, policy domains and governance levels need to cooperate (Head 2008; Van de Poel et al. 2012);

(iii) **uncertainty** pointing to a lack of knowledge or limited availability of evidence, for instance related to the risks or damages of action and non-action, the specific relationship between causes, consequences and side-effects of a problem, but also the fragmentation of knowledge across different stakeholders (Van Bueren et al. 2003; Newman and Head 2017).

Consequently, the higher the contestation, complexity and uncertainty of the problem underlying a particular challenge, the higher its wickedness and the more difficult might it be for (innovation) policy to frame societal challenges as to derive clear, legitimate and broadly supported missions from it. The degree of convergence/divergence of the problem statement depends on how (severe) different stakeholders perceive a problem, or contest a specific narrative about the challenge. Examples can be found in the recent discourses around climate change, genetically modified food or inequality. Problem divergence increases if (scientifically) accepted knowledge on a problem is lacking, the division of responsibilities to address the problem is not clear or institutional complexity is high (see Table 1). In contrast, problem statements are likely to converge when different stakeholders can agree on a problem framing and the importance of tackling it (lowers contestation), responsibilities for addressing the problem – in e.g. institutional or geographical terms – are clear (lowers complexity), and when the main causes and effects of a problem are fairly understood (lowers uncertainty).

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1 Wicked problems are also known as persistent problems in the transition literature (Rotmans and Loorbach 2009; Schuitmaker 2012). Other terms such as unstructured or incorrigible problems (Hoppe 2011), complex problems (May et al. 2013), or grand challenges (Cagnin et al. 2012; Kuhlmann and Rip 2014) are related.
Table 1: The wickedness of societal problems

|                          | Contestation:                      | Complexity:                     | Uncertainty:              |
|--------------------------|------------------------------------|---------------------------------|--------------------------|
|                          | Stakeholder divergence, normativity| High                            | Low                      |
|                          | Institutional and situational      | High                            | Low                      |
|                          | Lack or fragmentation of knowledge | High                            | Low                      |

| Problem statement | Divergence                | Convergence            |

Mission-oriented approaches that underestimate contestation and focus on scientific or technological uncertainties as the root of the problem run the risk of building their arguments on the assumption that the problem itself is well understood and widely shared (‘tamed’). This is especially apparent in the motto of “big science deployed to meet big problems” which did not only drive the policy logic in the 1960s, but is still referred to in some present-day proposals (Mazzucato 2017, p. 7). However, ‘hard facts’ no longer necessarily dominate ‘soft values’ in the context of social problems (Funtowicz and Ravetz 1993). The scientific evidence base on how to best address future societal needs is generally not considered as strong by all stakeholders involved, and this is likely to remain so in the future. Instead, different framings and attitudes to evidence and data usually co-exist and shape policy design and implementation (Turnpenny et al. 2009).

As emphasized by Daviter (2017), governing wicked problems comes with a trade-off. A ‘taming strategy’ that prioritizes one way of problem-solving and excludes competing perspectives may facilitate governability, but at the same time comes at high costs of problem reflexivity. If problem identification is based on specific epistemic knowledge of a certain group of experts, it may well allow faster agreement and action. On the other hand, the stifling of conflicts and competing perspectives in the policy process might not only reduce the quality but in the end also provoke resistance against the mission design.

3.2. The solution side: Diverging or converging views on innovative solutions

Contributions from policy sciences are valuable for determining the wickedness of problems but have not drawn a clear distinction between societal problems and their solutions yet. Instead, for typical wicked problems such as poverty, drug traffic and ghettos, it is assumed that the definition of a problem and the definition of a solution emerge gradually and in tandem. This assumption of inseparability of problems and solutions links back to the original contribution by Rittel and Webber (1973) who argued, from a governmental planning perspective, that social problems “can’t be defined until the solution has been found” (Rittel and Webber 1973, p. 161).

Insights from innovation and transition studies are useful to shed new light on how new solutions (i.e. innovations) emerge, why they diffuse or not diffuse, and how these processes can be supported by policy to solve societal challenges. Even if there is growing consensus on a problem statement (e.g.,

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2 The ‘ghetto’ problem was used by Nelson as archetypical counter-example to the ‘moon’ problem. While moon problems have relatively clear goals and technological solutions, ghetto problems are rather wicked in nature. On this, see Nelson (1974).
greenhouse gas emissions are too high), proposed solutions typically diverge between different stakeholders (e.g., carbon tax, subsidies for renewable energy, subsidies for carbon capture and storage, expand nuclear energy). It is therefore important to recognize that, despite a relatively clear problem definition, solutions can still be subject to different degrees of contestation, complexity and uncertainty, resulting in a degree of wickedness of solutions that may well differ from the degrees of wickedness of the problem at hand. This can be explained as follows:

(i) **contestation** can emerge around the feasibility of a solution, the opportunities and threats of innovations for businesses, for users or for society as a whole. Actors usually build their opinions, for instance about whether better technologies or new social practices are necessary to tackle a societal problem, based on their institutional or cultural context (Wolsink 2000; Roeser 2011; Dignum et al. 2016). Such conflicting framings and interests restrict diffusion patterns, and can lead to the refusal of a technically feasible innovation due to particular norms and values (Wesseling et al. 2015).

(ii) **complexity** is related to the fact that novel technologies need to be combined and aligned with new forms of organising the socio-technical system and radical changes in social practices to achieve systemic change. The large-scale diffusion of renewable energy, for instance, calls for new technologies to balance supply and demand, but also for new governance institutions and behavioural change (Elzen et al. 2004; Walker and Cass 2007). Even though changes in practices appear incremental and small at first, the accumulation of ‘small wins’ may in the end bring about systemic transformation (Termeer et al. 2017; Termeer and Dewulf 2018).

(iii) **uncertainty** refers to a lack or fragmentation of knowledge on the feasibility of a solution, or the fact that multiple solutions seem to be possible and promising (technological and/or institutional) without indication which works best for tackling the challenge in reasonable time. A lack of clarity about effects and side-effects of innovations can reduce the legitimacy and broad acceptance, and set back the development and diffusion of effective solutions (Sengers et al. 2010).

Consequently, we can say the higher the degree of contestation, complexity and uncertainty about an innovation, the more diverging the views on its solution potential (see Table 2).

### Table 2: The wickedness of innovative solutions

| Contestation: | High | Low |
|---------------|------|-----|
| Opinions on best solution |

| Complexity: | High | Low |
|-------------|------|-----|
| Need for systemic approaches |

| Uncertainty | High | Low |
|-------------|------|-----|
| Lack of knowledge on feasibility, reach and impact |

| Solution potential | Divergence | Convergence |
|--------------------|-------------|--------------|

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4. A problem-solution space to differentiate types of societal challenges

We attempt to improve analytical clarity about the context of missions and mission-oriented innovation policies by conceptualizing the underlying problem-solution structure. We focus on how problem statements and views on potential solutions may diverge or converge. Based on the categorization in Section 3, we can characterize four problem-solution constellations and derive a two-dimensional problem-solution space (Table 3). This problem-solution space will further allow us to locate and characterise different societal challenge-led mission policies based on the divergence/convergence of the societal problems and solutions.

Table 3: A two-dimensional problem-solution space to contextualize missions

| Diverging views on solutions | Converging views on solutions |
|-----------------------------|-------------------------------|
| I. Disorientation | II. Problem in search of a solution |
| High wickedness of the problem due to i) broadly framed challenge ii) lacking problem legitimacy (societal, geographical, temporal) iii) limited knowledge on problem nature | High wickedness of the solution due to i) no (shared) vision on feasible solution, vague and disputed ideas ii) fragmented approaches, low willingness to cooperate iii) limited knowledge on effects and side effects |
| High wickedness of the solution due to i) no (shared) vision on feasible solution, vague and disputed ideas ii) fragmented approaches, low willingness to cooperate iii) limited knowledge on effects and side effects | High wickedness of the solution as in I |
| Example: sustainable agriculture | Example: obesity |
| III. Solution in search of a problem | IV. Alignment |
| High wickedness of the problem as in I. | Wickedness of the problem reduced as in II. |
| Wickedness of the solution reduced due to i) concrete expectations on technological, or institutional innovations ii) new business models and integrated approaches iii) claims on feasibility and (positive/negative) societal impact of innovation | Wickedness of the solution reduced as in III; societal embedding limited |
| Example: self-driving car | Examples: smoking ban, CCTV, wind energy |

3 We are aware that problems or solution convergence (divergence) is neither a discrete nor a self-contained phenomenon; each of the illustrated problem-solution structures represents a more symbolic and simplified representation of a continuum.
Below we illustrate typical governance modes and arrangements\(^4\) for each of the four problem-solution constellations, and discuss policy strategies to coordinate actions, to involve actors and to progress on the current state\(^5\).

**Quadrant I: Disorientation**

The top-left quadrant characterises a ‘highly wicked’ problem-solution constellation in which neither a consensus on the problem definition nor on a clear, realistic or practicable idea about solutions has developed. Such a situation of diverging problems and diverging solutions can be illustrated with the example of sustainable agriculture (see Box 1). Different stakeholders are highly influenced by their particular background and knowledge in understanding and assessing the situation, and driven by their individual interests, values and opinions on what a desirable future state could be. Hence, a commonly accepted framing of the societal challenge in terms of the real problems and the best way(s) to solve them is missing.

**Box 1: Sustainable agriculture - a diverging problem with diverging solutions**

| After World War 2, Agricultural Policy was first and foremost aiming to secure Europe’s internal food production and market. Driven by technological innovations (Grin et al. 2004) and farm size increases, productivity has doubled (de Wit et al. 2011). European agriculture can be typified by what Duru et al. (2015) define as a ‘productivist’ paradigm. This paradigm, however, has also led to a diverse set of large adverse social and ecological impacts (Henle et al. 2008; Stoate et al. 2009) like a strong decline of insects and birds (Sanderson et al. 2013), high nitrogen deposition levels (Bobbink et al. 2010), high impact on climate change, low animal welfare and low or negative income for farmers (CBS statline 2018). Different societal groups (firms, farmers, NGOs, retailers) stress different problems and propose solutions for these problems. Apart from specific groups focusing on specific problems, also different and incompatible holistic visions dominate the debate. The two extremes are 1) the belief in large-scale agriculture in which high tech knowledge is able to deliver high amounts and high quality products within environmental constraints and 2) the belief in small scale organic farming practices with low inputs of pesticides and fertilizer (Morgan and Murdoch 2000; Lamine 2011). Different perceptions of the problem and different views on solutions that are highly contested make it very hard to develop a shared vision on a sustainable agricultural system. |

\(^4\) We build on Borrás and Edler (2014) seeing governance as “... a way in which societal and state actors intentionally interact [...] by regulating issues of societal concern, defining the processes and direction of how technological artefacts and innovations are produced, and shaping how these are introduced, absorbed, diffused and used within society and economy” (Borrás and Edler 2014, p. 14). This definition is useful because of its comprehensibility from setting direction to the societal diffusion of innovations, on the one hand, and its emphasis on a range of actors and their intentionality in dealing with issues of social concern, on the other hand.

\(^5\) Importantly, our aim is not to conceptualize the role of actors for different problem-solution constellations. We do not address questions regarding the best actor arrangement for a specific problem-solution structure but see in policy, irrespective of governance levels, a central role for taking collective decisions and mobilising societal resources for societal ends (Meadowcroft, 2009). At the same time we acknowledge that socially-led stakeholders with a specific interest in the issue (e.g. NGOs, companies, innovators, experts, researchers, everyday users, social entrepreneurs, civil society associations of people affected) may dominate, support or accelerate political dynamics.
In a highly wicked situation, scientific evidence regarding problem causes and consequences is crucial to learn about and better specify the problem. However, policymaking in the context of societal problems can rarely be based on objectivity and technical evidence alone, but involves trade-off between competing social values (Parkhurst 2017). Processes of social learning (Ison et al. 2015), collective visioning (Loorbach 2010; Hajer and Pelzer 2018) and participatory governance and research practices (Weber 2006; Cagnin et al. 2012) allow different actors to cooperate despite their diverging viewpoints and backgrounds. New institutional arrangements are needed to provide a platform for discussion, allow for conflict and negotiation, and enable the development of a collective understanding. It is about increasing awareness about different framings and explanations of a problem, accommodating these differences, and building mutual expectations (convergence). Recent studies suggest that the more open and inclusive these processes of learning are, not only for policy actors but also for societal actors (experts and non-experts such as citizens, firms, civil society and interest organizations), the higher will be the legitimacy of framing and shaping the problem (Wesseling and Edquist 2018; Boon and Edler 2018).

Quadrant II: Problem in search of a solution

The top-right quadrant typifies a situation in which a dominant definition of a societal problem enjoying broad societal acceptance has emerged, for instance due to convincing evidence or rising urgency. Despite a rather clear problem framing, as exemplified for the case of obesity (see Box 2), multiple solutions to approach the problem are still conceivable (both technological and institutional innovation), and ideas on how to achieve transformation or solve the challenge are vague, uncertain or disputed.

Box 2: Obesity - a converging problem with diverging solutions

Obesity is under the top three global social burdens generated by human beings, after smoking and armed violence/war/terrorism (Dobbs et al. 2014). Specialized agencies stress the obesity epidemic as a societal problem (WHO 2000), and politicians followed, particularly emphasizing childhood obesity (Popkin and Larsen-Gordon 2004; Dobbs et al. 2014). The shift from seeing obesity as a personal matter to seeing obesity as a major policy issue can be explained not only by the rising obesity rates across Europe and the US, but also by increasing scientific understanding about the risk of other chronic diseases (type 2 diabetes, heart diseases, cancer) and the society-wide costs obesity causes due to treatment expenses or increasing health inequality. (Childhood) obesity is nowadays recognized as highly societally-induced, namely as a systemic problem rooted more in lifestyle choices, dietary choices as well as socio-economic conditions than only in genetic predisposition (HM Government 2016). Despite increasing recognition that only individualized, science-based treatment based on drugs, therapy or bariatric surgery will not be sufficient and effective enough, as yet there are no comprehensive solutions or policy models of how to prevent or stop the rising obesity rates. Obesity requires coordinated and cross-sectional action beyond the health sector, including agriculture, manufacturing and retailing (for changing product ingredients and availability, pricing, portions), education, media and culture (for building knowledge, skills, and awareness around food and physical activity), transportation and urban planning (for car-free and physical activity based mobility) or economic policies (for subsidies or taxation of food) (Lang and Rayner 2007; Gortmaker et al. 2011). For instance, Dobbs et al. (2014) identified 74 types of interventions in 18 areas worldwide, but solid evidence on how well these intervention work or on their societal impact is scarce.
If a dominant definition of a societal problem has emerged and enjoys broad acceptance, *setting priorities and targets* may be a means for policy to overcome coordination and directionality failures (Weber and Rohrarcher 2012), to pool knowledge and to accelerate progress towards meeting the challenge. For situations in which a converging problem understanding has developed, the formulation of clear and approachable research and innovation missions, as recently advocated in Mazzucato (2018b), could indeed be an effective instrument for a targeted transformation. In this way, a joint vision about the future can be translated and operationalized in form of missions with clear goals and target values that are realistic and in line with the envisioned future state. The question of how innovation can contribute to achieve the mission is still open and uncertain at this stage, which requires exploration and experimentation with different types of solutions.

**Quadrant III: Solution in search of a problem**

The bottom-left quadrant of Table 3 refers to a situation in which shared and optimistic expectations have emerged regarding the feasibility and importance of an innovation. Yet, the nexus between a societal problem and the innovation is ill-defined, normatively loaded or faces public reluctance due to uncertainties regarding risks or trade-offs. As such, the solution appears to be in search of a concrete problem to showcase its feasibility (see the example of self-driving cars Box 3). Social barriers originating from the prevalent practices, limited legitimacy and awareness of the need for change hamper the societal embedding of the innovation to provide a large-scale solution for a societal challenge.

**Box 3: Automated vehicle technology - a converging solution with diverging problem perceptions**

Several terms like autonomous vehicles, self-driving cars, driverless vehicles, robotic cars are used to describe the technology where car technology takes over the control of the car from a human being. The technology can best be understood through levels of automated driving where on the low-end level 1 refers to driver assistance and on the high-end level 6 refers to full automated driving (SAE 2014). Car manufacturers have been working on innovative solutions to create more comfort for the driver using several forms of automation. Cruise control was already developed in 1945. Since then car manufacturers have developed a range of technologies like adaptive cruise control, lane departure warning, parking assist and break assist to increase comfort and driving safety. Google changed the paradigm that automation technology should aid the driver by introducing a self-driving car that was designed to replace the driver completely. Over the years the set of reasons that support the development of automated vehicle technology is increasing. Where driving comfort and safety were original arguments, later many more arguments were added like: 1) increased productivity as the car becomes an office space, 2) higher capacity of highways and therefore reduction of congestion, 3) solution for an aging society where disabled elderly can now enjoy car mobility, 4) reduction of employee costs for taxi companies and 5) allowing for improved car sharing schemes (Van der Meer 2017; Brummelen et al. 2018). The increasing set of societal benefits that are argued to be stemming from this solution is a clear sign that solution convergence has taken place, but that the solution is still looking for societal problems to link to in order to increase its legitimacy.
A situation of converging solutions but still diverging problem perceptions may require high reflexivity on the part of policy (Weber and Rohracher 2012), to evaluate the validity of the innovation’s claim and, more generally, to balance expectations and future application potentials. Without sufficient reflexivity, the implementation of targeted policies focussing on one specific innovation runs the risk of low acceptance. Here, low societal acceptance can be due to high uncertainty about the effects, side effects and the real contribution a proposed solution can make to solve a societal challenge. Such a situation may give room for stakeholders (e.g. incumbent firms) to capture processes of problem framing according to their interests and own benefits (Frenken 2017).

**Quadrant IV: Alignment**

The bottom-right quadrant of Table 3 characterises a situation in which both societal problems are relatively well understood and supported, and in which views on promising solutions have converged. Examples for a constellation characterised by convergence of both the problem perception and the solutions. Examples of innovations in this quadrant include wind energy, CCTV and the regulatory ban on second-hand-smoking (SHS). These examples are discussed in more detail in Section 5, where we discuss their biographies as a historical process from wicked problem-solution constellations (Quadrant I) to widely accepted and well-aligned problem-solution constellations (Quadrant IV).

Situations in which societal problems are relatively well understood and broadly supported, and in which views on solutions with high potential have converged, call for policies that focus the targeted development and diffusion of innovations, and the embedding (widening and deepening) of new social practices. Diffusion-oriented policies are essential if convergence around a solution for a clear, legitimate problem has been achieved, but innovations are not able to fully compete on the mainstream market (e.g. renewable energies), due to incumbent products that have benefited from decades of incremental improvement (Geels 2004), or missing demand to upscale and implement the innovation on a broad basis (Boon and Edler 2018). With the advent of converging structures, systemic innovation policies can come into play to support market creation, the diffusion of new technologies or the broader societal embedding of particular ways of acting.

5. A role for policy to move towards converging problem-solution constellations? Three stylized policy pathways

Following our framework, mission oriented innovation policy can be understood as an attempt to accelerate progress in solving societal challenges, by shaping the direction, diffusion and embedding of innovations in society. So far, we have argued that given the variations in the ‘wickedness’ of societal challenges and their associated problem-solution constellations, a one-size-fits-all approach to designing mission-oriented policies and innovation missions seems not appropriate. In what follows, we make an attempt to characterise how policy might stimulate movements away from a ‘wicked’ towards an aligned problem-solution constellation\(^6\), and to support the creation of a stable basis for

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\(^6\) The idea of movement contradicts with the assumptions made in the policy sciences literature (e.g. Alford and Head 2017; Hoppe 2011). This literature takes a static perspective and sees wickedness as an inherent quality of
society-wide uptake of innovations. Hereby, a policy pathway constitutes a movement in the matrix reflecting the processes of problem and solution convergence. Our arguments are supported by three empirical cases (Box 4-6), based on which we point to possible barriers and limitations associated with a certain pathway and potential approaches to govern contestation, complexity and uncertainty for different stages.

Table 4 Different pathways for MIP in the problem-solution space

|                | Diverging views on the problem | Converging views on the problem |
|----------------|-------------------------------|---------------------------------|
| Diverging views on solutions | Disorientation                | Problem in search of a solution |
|                |                               | (3)                             |
| Converging views on solutions | Solution in search of a problem | (2)                             |
|                |                               | Alignment                       |

The problem-led pathway (1)

A problem-led pathway (1) aims at creating a broadly legitimized and defined societal problem framing (movement towards a converging problem), based on which the search for and experiments with different solution can build. The initial focus is on comprehending the multiple dimensions, causes and effects of a problem for different social groups, and to stimulate the development of a common, converging vision about a desired future. Different perceptions, expectations and claims for action or non-action to mitigate or tackle a problem will be brought on the table.

As the case of second-hand smoking shows (Box 4), even though contestation can defer the creation of a shared vision significantly and for a long time, the collection of evidence contributed to an improved understanding of the societal costs of second-hand smoking. Once the problem of second-hand smoking was delineated from smoking, and became publicly accepted as a problem, efforts were directed towards experimenting with different solutions (technological, institutional, or a combination of these) and diffusing them later on.

A problem-led policy strategy combines the a mission orientation with reflexive governance (Voss and Bornemann 2011) and social learning (Ison et al. 2015) to comprehend the multiple dimensions of a societal problem, and to increase awareness about the normative choices policy has to make in defining, selecting and setting innovation missions or solution-seeking strategies. Also, a clear and uniform problem framing may be difficult to achieve, due to the lack of knowledge, conflicting interests or the high stakes involved. Fast decisions requiring the acceptance of a certain problem framing can create a certain problem/solution situations that cannot be changed. On the contrary, the literature on social learning (e.g. Ison et al. 2015) suggests that wicked problems can be tamed through framing. In doing so, a problem is simplified but remains wicked in nature. We build on the latter assumption by emphasizing the need for technical and social learning about different solutions, expectations and problem perceptions to arrive a converging and stable constellations.
new breeding ground for refusal (bounce-back effects), especially if the initially high expectation for a solution cannot be met due to technological or economic barriers (e.g. no feasible large-scale solutions, or high costs which impede the market creation and finance for innovations).

**Box 4: The case of smoking bans to reduce second-hand smoking: A problem-driven pathway**

**Stage 1: convergence around secondhand smoking as a societal problem**

Smoking is responsible for about six million annual deaths worldwide. This societal problem has however remained contested and unclear for a long time. Since the 1970s, the scientific evidence in the US on the consequences of secondhand smoking (SHS) has been mounting with impactful Surgeon General reports in 1971 (first proposing a government ban on smoking in public places due to anticipated health risks; Surgeon General 1971), in 1972 (identified SHS as a health risk; Surgeon General 1972) and in 1986 (conclusive evidence on SHS causing cancer and health problems in children; Surgeon General 1986). Subsequently, a 1993 EPA report classified SHS as a Group A carcinogen and determined that SHS leads to various diseases (EPA 1993), which provided grounds for the EPA to regulate smoking. Over this entire period, the tobacco industry questioned scientific evidence of the adverse health effects of SHS (Widome et al. 2010), and even started smear campaigns against the EPA (Oreskes and Conway 2010) (contestation). They invested significantly in smoking advertisement to associate smoking with coolness, strength and freedom (Ibid). Due to this well-organized lobby and framing, SHS was not accepted by all stakeholders, scientific evidence on SHS was disputed (creating problem uncertainty), and diverging norms were actively promoted (contesting the problem). The debate was settled with the 2006 Surgeon General report that concluded that “the debate is over” and ‘the science is clear’ that SHS causes lung cancer and heart disease in nonsmokers, among many other conditions” (Surgeon General 2006, in: Hyland et al. 2012).

**Stage 2: convergence around smoking bans as a solution**

With growing evidence on the adverse health effects of SHS, the range of solutions had increased (solution divergence): In the 1970s, governments started to tax cigarettes and control advertisement (Oreskes and Conway 2010), after the 1986 Surgeon General report, many local initiatives started banning smoking because of SHS, and in 1995 the first state-wide smoking ban in restaurants was issued in California (Widome et al. 2010). Over this period public contestation slowly decreased as the norm changed from ‘smoking bans impinge on people’s freedom to smoke’, to ‘smoking in public places harms the health of others’. Smoking bans were issued at both the local and state level, with the result that by 2010 “41% of the US population lives in a community that requires all indoor workplaces (including restaurants and bars) to be completely smoke-free” (Widome et al. 2010).

This converging trend around smoking bans, however, was preceded by strong industry contestation to this solution. Since the 1970s, the tobacco industry has strongly lobbied against any restrictions on smoking (Mandel and Glantz 2004; Oreskes and Conway 2010; Widome et al. 2010). Regulations were assailed with normative arguments related to infringement of freedom or with references to Communism and totalitarianism (Oreskes and Conway 2010). Industry offered alternative solutions aimed at reducing the negative externalities of smoking, such as better filters, cleaner tobacco and cigarette paper, or later e-cigarettes and inhalers (Oreskes and Conway 2010), and advocated for ventilated spaces (Mandel and Glantz 2004). The smoking lobby demanded public research funding for developing even safer cigarettes instead of bans and successfully pushed for laxer e-cigarette regulation
(Oreskes and Conway 2010), which mitigated convergence around the smoking ban solution. Also, a range of solutions have been developed to wean people off smoking, including replacements such as nicotine patches and gums, telephone quit lines or web-based services, non-nicotine pharmacotherapies or reinforced antismoking education in school (Bertollini et al. 2016). To conclude, although a range of solutions that link directly to the cause of smoking is needed to overcome the problem of SHS, smoking bans have, despite aggressive industry opposition, become increasingly accepted as a central part of the solution-range (Hyland et al. 2012; Bertollini et al. 2016) (solution convergence).

**The solution-led pathway (2)**

The solution-led pathway (2) constitutes in contrast to a problem-led pathway a bottom-up or solution-push approach centred around the development of single innovations. Initially, their contribution to meeting a societal challenge is not clear, not made explicit or not intended. This pathway is consistent with policies that legitimate funding for basic research with reference to science’s broad potential to solve societal challenges (Dosi et al. 2006; Mazzucato 2017). It also fits with disruptive innovation strategies applied by technology companies such as Airbnb, Google, Juul and Uber, who often justify their lack of regulatory compliance by their contribution to solving health, social cohesion and sustainability issues (Schor 2016).

As evident in the case of CCTV in the UK (Box 5), once an innovation ‘finds’ a societal problem, however, the build-up of expectations can be a major driver for its societal embedding. In such cases, uptake of a (technological or institutional) solution could take place despite the initially open, diffuse or even contested problem definition, or without profound evidence about the effectiveness of the solution.

Along a solution-led pathway, focus is on the development of solutions, while the attention to societal problem definitions and trade-offs between societal values is underrepresented. Particularly solution providers from science or industry, and possibly from other stakeholders with strategic interests, might try to influence the societal framing of the problems to which the solution could contribute. If the effectiveness and societal consequences of the solution are not fully clear, this pathway bears the risk of societal barriers emerging along the way, ranging from limited public awareness and problem legitimacy (is safety at public places a problem that justifies large-scale surveillance?), uncertainty about the solution’s impact (is CCTV capable of increasing safety and reducing crime rates?), or limited willingness to implement the solution on a large scale (surveillance at which places and at what time?).
CCTV refers to video surveillance cameras used in public places. Its purpose is “mainly to deter and detect crime, disorder and antisocial behaviour”, but also “to help reduce the ‘fear of crime’” (Webster 2009 p. 11). Though CCTV systems have a long history in private spaces, its diffusion in public spaces started only in the 1990s. The United Kingdom (UK) is commonly regarded as the frontrunner in the deployment of CCTVs. The central government played a key role in the diffusion of CCTVs by advocating its use and financing most of the costs in the ‘Fight Against Crime’ (Webster 2009).

Stage 1: rapid solution convergence around CCTV to reduce crime without a clear problem understanding

The case of CCTV exemplifies a policy pathway in which CCTV had been early on framed as the key solution by the UK government (solution convergence). The government invested large sums in rolling out the technology without formal regulation. Instead, technical standardisation was achieved through self-regulation by service providers. In the process, the wickedness of the problem of crime was not acknowledged: the alleged benefits of CCTV to public safety were not weighted against other public values such as privacy or discrimination. Instead, the national government acted upon the belief, shared by the general public, that CCTV would be effective in reducing crime and feelings of unsafety. During the initial stages of diffusion, no evidence about the effects of CCTV was available, marking the policy uncertainty typical for wicked problems. The wicked nature of the CCTV solution is further exemplified by institutional complexity following from the involvement of different government agencies and service providers. In the absence of national legislation, CCTV systems developed common technical standards and operational procedures through voluntary self-regulation. According to Webster (2002), the involvement of the government in pushing CCTV technology explains why it allowed CCTV to be adopted by local agencies without much formal national regulation. National government removed some of the local regulatory hurdles, such as a planning permission for CCTV installation. CCTV also met contestation by particular advocacy groups (especially those concerned with privacy). Yet, as Webster (2002) indicates, policy networks marginalised critical views and alternative solutions as public discourse concentrated on the (alleged) benefits of the cameras, downplaying possible problems regarding privacy, admissible evidence in courts, discrimination and crime displacement effects.

Stage 2: developing an ex-post deeper understanding of the problem

Hence, we understand the initial CCTV policy by the UK’s national government as the key pillar in crime prevention as an instance of solution convergence without a comprehensive problem assessment (i.e. problem uncertainty). Slowly, in the wake of a more general turn to evidence-base policy-making and to prevent contestation, CCTV’s legitimacy was sought in empirical studies looking for crime-reduction effects of CCTV. Such evaluations can be understood as part of a process of problem convergence by reducing the problem uncertainty, as evaluation necessitates to define and measure crime in the first place. A systematic overview by Welsh and Ferrington (2009) found only a modest decrease in crime, which can almost fully be explained by the effectiveness of CCTV in car parks. Webster (2009), reviewing the UK evidence, also concludes that the evidence base is weak regarding the impact of CCTV on crime reduction. Interestingly, CCTV seems to be more effective to reduce antisocial and undesirable behaviour rather than to prevent real crimes. And, after several terrorist attacks, CCTV was further legitimised as useful in the prevention of terrorism.
The hybrid policy pathway (3)

A hybrid policy pathway follows a co-evolutionary logic, balancing problem and solution wickedness at the same time by experimenting in both directions and learning about the problem(s) in the course of finding solution(s). It may seem to be a promising course for wicked societal problems that are ill-defined and have no known solution, and might be pursued as a matter of urgency given the nature of the problem, high societal expectations or political pressure to act. For instance, dealing with societal problems of great urgency, also referred to as ‘super-wicked problems’ (Levin et al. 2012) might be best addressed by a co-evolutionary approach. Negotiating, balancing interests, together with performing experiments at a small-scale allows learning about outcomes, possible impact and potential for uptake.

However, as the Dutch case of wind energy shows (Box 6), it is possible that missions specified in such a situation can be misleading, for instance if expectations associated with an innovation cannot be met or specific goals are set based on unfounded assumptions. For onshore wind it turned out only later that the solution already converged upon generated unforeseen side effects in the phase of large-scale diffusion (e.g. visual, audible and safety effects of wind turbines), which slowed down the achievement of renewable energy targets and redirected the process of problem-solving convergence.

Box 6: The case of wind energy to reduce greenhouse gas emissions: a hybrid pathway

Stage 1: societal problems and targets stimulate initial local renewable energy solutions

The development of wind energy in the Netherlands started in the 1970s. Reasons for developing renewable energy technologies at that time were related to a range of problems: The oil crisis in 1973 and the negative effects of high fuel prices on the economy, declining fossil fuel reserves, or foreign dependencies related to fuel security. Wind energy was considered as a technology with high potential but with significant uncertainties regarding feasibility. The first period was characterized by investments in technology development for onshore wind turbines. The Dutch followed a so-called break-through strategy as there was a strong focus on developing highly complex large wind turbines which are most efficient from an engineering perspective (Garud and Karnøe 2003). There was optimism that engineers from the existing airplane industry in The Netherlands would be able to develop well-functioning large-scale turbines. This trajectory failed. During the 2000s, the Danes who followed a totally different, bricolage strategy – focusing on slowly upsaling small turbines - outcompeted the Dutch initiatives and only one Dutch turbine manufacturer (Lagerwey) survived.

In 1995 the Dutch government converged upon the problem by setting concrete targets for renewable electricity: 10% in 2020 (Economic Affairs 1995). The main arguments for setting such targets were the exhaustion of fossil fuel reserves and the emergence of climate change as a major societal problem (Economic Affairs 1997). A related, economic argument was that by getting experience with renewable energy now, the Dutch could regain an export position by building up a renewable energy industry. The target reduced institutional complexity as it provided clear guidance of the search (Economic Affairs 1995 p. 51). However, during the years that followed the diffusion of onshore wind energy did not develop according to expectations. Reasons for this were contestation by local opposition and by specific NGO’s complicated planning procedures, and struggles related to responsibilities between local, provincial and state government (i.e. high institutional complexity).
Stage 2: Problem convergence pushed different renewable energy solutions

To solve the above implementation problems for onshore wind, attention shifted slowly to offshore wind, which was not considered in the initial plans (Economic Affairs 1995). At the same time, climate change was increasingly perceived as a societal threat, spiked by Al Gore’s ‘An Inconvenient Truth’ in 2006, resulting in the Renewable Energy Directive (European Parliament & European Council 2009) that set a mandatory 14% renewable energy target as share of total final energy consumption for the Netherlands in 2020. This increased problem convergence meant that significant additional policy efforts were needed to reach the target. In this light, ambitious targets were initially set for offshore wind (institutional guidance), but offshore as a solution was strongly contested by liberal political parties due to the high electricity prices associated with this technology. Consequently, the policy attitude towards offshore wind in those days was still defined by uncertainty and could best be characterized as a hedging strategy: some investments to keep options open, but no intention to fully commit and invest massive resources (Wieczorek et al. 2013).

Stage 3: Solution convergence around offshore wind to meet the mandatory mission

Only recently, this attitude changed. The Dutch government was under pressure since the Netherlands was falling short in realizing its promised contribution to the European renewable energy target of 20% in 2020. Offshore wind was identified as the only available technology to quickly upscale the potential of renewables (reducing uncertainty) (SER 2013). The high-cost argument therefore was overruled, and later it turned out that offshore wind parks can be built at much lower costs than previously expected. This led to a surge of political and societal interest in the technology from 2016 onwards, and the current tender procedures are even prepared for subsidy-free offshore wind parks. This has led to strong solution convergence around offshore wind as a key technology in realizing renewable energy and carbon emission targets.

Following a hybrid pathway by aiming at a thorough understanding of the contestation, institutional complexity or uncertainty related to a potential solution and the societal problem at the same time, runs the risk of remaining stuck in an un-guided policy approach without realistic goals or a clear solution path. Set-backs are more likely to come from both sides, the inhibited specification of the ‘real’ problem or the unfounded selection of the ‘best’ solution, which might cause significant delays for a strategy initially build upon high expectations. However, if well managed, an iterative process of experimenting with new solutions, while better understanding the problem as well as the impacts of the new solution on the problem, offers a lot of learning potential.

6 Implications and conclusions

6.1. Implications for mission-oriented innovation policy

This paper set out an analytical contribution to the recent debate on the challenges of current societies and how mission-oriented innovation policy could help to meet them. Our aim was to provide a conceptual framework for a better contextualization of the plurality of ‘grand’ societal challenges, ranging from climate change, over energy and food security to public health or obesity that recently emerged in both scientific literature and innovation policy practice.
Our starting point was that the policy discourse about directionality and societal mission-orientation insufficiently considered the mission context. Undoubtedly, remaining vague and defining societal challenges in broad terms can be the preferred political strategy, to circumvent political conflicts or contestation, and to support acceptance on a broad basis. Such a strategy, however, comes at a price, because disregarding the normative elements involved in prioritizing a certain problem framing (e.g. to narrow down and formulate a specific mission), or in prioritizing a certain innovation (e.g. to accelerate in solving the problem) can impede the legitimacy of policy, the public acceptance of an innovation or its uptake across different industries or locations. Clearly, the emergence of opposition during the upscaling process of an innovation cannot be ruled out when designing MIP, just as conflicting evidence on problem causes or negative effects of the alleged solutions may become known afterwards.

We argue that the widening of the innovation policy agenda towards societal challenges bears governance implications along two dimensions. At the problem side, a non-trivial part of mission-oriented innovation policy is to identify, select and demarcate a societal challenge into a clear problem formulation. At the solution side, societal challenges often require solutions that go beyond the traditional science- and technology-based strategies still being pursued by most universities, firms and governments. As such, not just problems but also solutions can be considered to be wicked. Solutions have different forms, result from various types of search processes, be of technological or institutional nature, and involve different actors in their development and diffusion. Hence, the derivation of a universal formula for effective societal mission-oriented policies might be both hard to achieve and ineffective in dealing with societal challenges.

Societal challenges, then, can fundamentally differ in terms of both the problem framings and the search processes needed to generate solutions. By contextualizing societal challenges along both the problem and solution side, we depart from one-size-fits-all policy approaches and suggest four stylized types of problem-solution constellations (I. Disorientation, II. Problem without a solution, III. Solution without a problem, IV. Alignment). Assessing the location of a particular societal challenge in this problem-solution space seems necessary to consider the specific character of the challenge, and to pursue targeted policy strategies to achieve public acceptance and institutional support for the mission at hand.

Moreover, the characterization of three stylized policy pathways suggests a process-oriented mission-oriented innovation policy, by revealing the different routes and phases policy may take – intentionally or non-intentionally – in dealing with the changing patterns of uncertainty, contestation and complexity involved in pursuing societal missions. Our elaboration makes clear that, if the aim of mission-oriented policies is to find effective solutions for diffusely defined challenges, more dynamic and flexible approaches are needed. Setting the direction for innovation activity by defining targets at the outset might not be sufficient. In fact, it is more about learning how to deal with the degrees of contestation, complexity and uncertainty involved in addressing societal issues, and to govern a converging problem-solution nexus in a reflexive way.

6.2 Implications for the implementation of mission-oriented policies in Europe

Against the backdrop of our more differentiated perspective on missions, we can now take a look at the current debates about mission-oriented policies in Europe. With the launch of the still ongoing Horizon 2020 European Framework Programme for Research and Innovation, the orientation of innovation
policy towards societal challenges has obtained a prominent place on the funding landscape. A major part of Horizon 2020 is earmarked for research and innovation activities on seven societal challenges. However, it became evident in the aftermath of the interim evaluation that the prominence of societal challenges in the Horizon 2020 programme has proven insufficient to re-orient significant parts of research and innovation activities towards clear and ambitious societal goals (Lamy et al. 2017; EC 2017). As long as the modalities of research and innovation funding programmes remain by and large the same as they have been for the past thirty years, the gap between ambitious long-term and higher-order goals, on the one hand, and the prescription of specific topics as defined in work programmes, on the other hand, will continue to be too wide to lead to the ambitious or even transformative solution-oriented innovations needed to tackle grand societal challenges.

In recognising these deficits, the specification of ‘missions’ at an intermediate level of granularity was suggested as focusing devices to bridge the gap between societal challenges on the one hand and specific research and innovation projects on the other. Such missions should ensure that the intended impact of research and innovation activities funded by the Framework Programme can be achieved (Lamy et al. 2017). With the programmatic paper on mission-orientation in European research and innovation policy (Mazzucato 2018b), the rationales for a mission-oriented approach have been visibly spelled out as a trigger of further political debate and public consultation at the European level. Furthermore, it has been suggested to formulate missions that are goal-oriented, measurable and time-bound as to make missions more concrete and orchestrate innovation activities at multiple ends.

This approach has been largely followed in the proposal for Horizon Europe as presented in June 2018 (EC 2018). It is a major step forward because first of all it recognises the wicked nature of the societal challenges in the focus of the Framework Programme. Second, by suggesting to translate missions into bold, inspirational plans with clear targets, it promises to make them manageable by an institution that relies on formal technocratic procedures. Third, a debate has started on what fields of research might be appropriate for missions. These are still under discussion, and the suggestions range from targeted technological missions to truly wicked areas in need of socio-technical transformation.

The initial ideas for a mission-oriented approach in Horizon Europe have been critically discussed in several contexts, not least by studies and expert groups set up by the European Commission itself. Four main points of criticism of the approach can be extracted to which our more differentiated approach to missions indicates promising responses.

First, the too undifferentiated understanding of missions in the Commission documents, which reflects a one-size-fits-all and technocratic interpretation of mission-oriented policies. It assumes the existence of converging problem and/or solution specifications, which in the reality of most societal challenges do not exist. It is here that our problems-solution framework can be put to use. Most of the challenges formulated by the European Union and its Member States are arguably best described as wicked. Little convergence so far has been achieved regarding concrete problem formulations in most aspects of

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7 These seven areas are: Health, demographic change and wellbeing; Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the Bioeconomy; Secure, clean and efficient energy; Smart, green and integrated transport; Climate action, environment, resource efficiency and raw materials; Europe in a changing world - inclusive, innovative and reflective societies; Secure societies - protecting freedom and security of Europe and its citizens.

8 See for instance the reports by two high-level groups (ESIR 2017, RISE 2017), analytical studies (JIIP 2018a, 2018b) and the foresight activity in preparation of Horizon Europe (Weber et al. 2018).
climate change, cybersecurity, sustainable agriculture and healthy ageing, and the innovation-led solutions are still unclear. Hence, for each of the challenges, one may ask how sufficient convergence can take place in terms of problem formulation, including specific and measurable targets, before embarking on ambitious innovation programs (Frenken 2017). As long as challenges remain broadly defined, specific interest groups – and their preferred solutions – are likely to capture the policy process. By taken differences across societal challenges in terms of convergence and divergence in the problem-solutions space into account, a more differentiated approach to mission-oriented policies can be developed.

A second important point of criticism refers to the too narrow range of actors and stakeholders involved in the definition of problems and the ideation of solutions. Wicked and uncertain problems, however, require a wide spectrum of problem framings and potential solutions. Initially, the European Commission envisaged a wide consultation, involving also citizens, in the specification of missions, but this process has not taken place so far. The dimension of contestation, as suggested in our framework, captures this necessity of giving enough room to diverging opinions and ideas to be harvested, before convergence around a shared understanding of the problem and of the solution(s) agenda can take place.

A third criticism stresses the necessity to fundamentally rethink the design of mission-oriented funding programmes. Past Framework Programmes, and even the societal challenges part of Horizon 2020, predefined strategic research agendas down to the level of specific research topics. If, however, the dimension of uncertainty as suggested in our framework is taken seriously, then a much more ‘tentative’ approach to programme design needs to be pursued (Kuhlmann et al. 2019). In practice, this means that an open, multi-stage and selective process of moving from a large number of smaller exploratory projects to a limited number of large-scale research and innovation initiatives would allow learning from the early stages. A learning phase will show which potential solutions might be promising for being carried forward in order to address a mission-type problem, while others can be discarded. The three types of pathways suggested in our framework indicate that different strategies to move towards convergence in terms of both problem and solution are possible and that programme design should enable pursuing these different pathways. This kind of multi-stage programme design has been tested in a number of national programmes already, which could serve as source of inspiration for the future design of mission-oriented elements of Horizon Europe.9

Finally, a fourth criticism of the Horizon Europe approach to missions points to the importance of rethinking the governance approach, and in particular policy coordination needs, if the ambitions of a mission-oriented programme are to be achieved. These ambitions go well beyond the delivery of new innovative solutions, and aim at contributing effectively to resolving societal challenges. In other words, much more attention is paid to the ultimate impact of research and innovation, and how research and innovation outcomes are actually generalised, scaled and diffused in order to realise missions and trigger transformative change processes. This implies that mission-oriented research and innovation activities cannot be seen in isolation, but need to be embedded in domain-specific policies of the areas in question. Effective coordination and alignment between R&I policy and sectoral/thematic policies, multi-level coordination between European-level research and local implementation, and the

9 See for instance the Swedish programme ‘Challenge-Driven Innovation’ or the French initiative ‘Commission Innovation 2030’, which both followed a multi-stage model.
orchestration with private and third sector stakeholders pose serious challenges for the governance of missions. In terms of our conceptual framework, this points to the importance of the dimension of complexity and the need to move from a diverging to a more converging situation also in this regard. This poses high demands on the management of mission-oriented programmes, which will need to be much more pro-actively supervised in order to facilitate the alignment between the different types of actors and stakeholders playing a role in the realisation of a mission.

6.3. Implications for further research

Our analytical framework to contextualize mission-oriented innovation policy builds on academic literature in policy and innovation studies based on which we map a two-dimensional problem-solution space. With our brief empirical cases on smoking bans, CCTV and wind energy we could draw first lessons on how different dimensions of problem and solution wickedness may play together and change over time, as well as on the different strategies a mission-oriented policy can take to govern this process. Our framework emphasises the need for new governance modes involving new actors, such as users or other stakeholders, more reflexive strategies that facilitate adaptations in response to new knowledge on the problem, its causes and societal significance, and new developments with regard to the envisaged solution, its effectiveness or side-effects (Loorbach 2010; Shove and Walker 2010; Bugge et al. 2018). However, more empirical research and investigations of policy practices are needed to further develop the proposed process-oriented perspective on mission-oriented policies.

Necessary steps in this direction should include: First, empirical investigations regarding the drivers and barriers of policy pathways, in particular the difficulties in governing problem and solution wickedness in different institutional or geographical contexts (Coenen et al. 2012). Our cases of policy pathways serve only as first stylized examples. We would need more empirical insights on how specific geographical and institutional conditions or multi-level arrangements can foster or hamper the governance of convergence at both the problem and solution side.

Second, the interplay of problem-solution constellations and policy mixes along distinct pathways. Given that most societal problems cannot be tackled with a single solution, a set of solutions is typically necessary, and this requires the implementation of a mix of policy measures and instruments along the mission’s lines. Recent literature on policy mixes for innovation and sustainable transitions (see e.g. Borrás and Edquist 2013; Rogge and Reichardt 2016; Kern et al. 2017) can serve as valuable reference here.

Third, the interdependencies between mission-oriented innovation policies and socio-technical innovation systems. System thinking could provide a framework for understanding how system components (i.e. actors, institutions, network and materiality) interact with different policy designs (Hoppmann et al. 2014), how they influence the formulation of missions and the search paths for solutions. So far, innovation systems have been defined around nations, sectors and technologies, but focused mostly on the supply of innovation. More attention should be paid also to the demand for innovation by defining innovation systems around societal problems or specific missions.
References

Alford J, Head BW (2017) Wicked and less wicked problems: a typology and a contingency framework. Policy and Society 36:397–413

Alkemade F, Hekkert MP, Negro SO (2011) Transition policy and innovation policy: Friends or foes? Environmental Innovation and Societal Transitions 1:125–129.

Bertolini R, Ribeiro S, Mauer-Stender K, Galea G (2016) Tobacco control in Europe: A policy review. European Respiratory Review 25:151–157.

Bobbink R, Hicks K, Galloway J, et al (2010) Global assessment of nitrogen deposition effects on terrestrial plant diversity: a synthesis. Ecological applications 20:30–59

Boekholt P (2010) The Evolution of Innovation Paradigms and their Influence on Research, Technological Development and Innovation Policy Instruments. In: The Theory and Practice of Innovation Policy. Edward Elgar Publishing

Boon W, Edler J (2018) Demand, challenges, and innovation. Making sense of new trends in innovation policy. Science and Public Policy. doi: 10.1093/scipol/scy014

Borrás S, Edler J (2014) Introduction on governance, systems and change. The Governance of Socio-Technical Systems: Explaining Change 1–22

Borrás S, Edquist C (2013) The choice of innovation policy instruments. Technological Forecasting and Social Change 80:1513–1522.

Brummelen JV, O’Brien M, Gruyer D, Najjaran H (2018) Autonomous vehicle perception: The technology of today and tomorrow. Transportation Research Part C: Emerging Technologies 89:384–406

Bugge MM, Coenen L, Branstad A (2018) Governing socio-technical change: Orchestrating demand for assisted living in ageing societies. Science and Public Policy 45:468–479

Cagnin C, Amanatidou E, Keenan M (2012) Orienting European innovation systems towards grand challenges and the roles that FTA can play. Science and Public Policy 39:140

Cantner U, Pyka A (2001) Classifying technology policy from an evolutionary perspective. Research Policy 30:759–775

Carley M, Christie I (2017) Managing sustainable development. Earthscan Publications, London

CBS statline (2018) Statistic Netherlands https://opendata.cbs.nl/statline/#/CBS/en/, accessed March 2018

Coenen L, Benneworth P, Truffer B (2012) Toward a spatial perspective on sustainability transitions. Research Policy 41:968–979

Daviter F (2017) Coping, taming or solving: alternative approaches to the governance of wicked problems. Policy Studies 38:571–588

de Wit M, Londo M, Faaij A (2011) Productivity developments in European agriculture: Relations to and opportunities for biomass production. Renewable and Sustainable Energy Reviews 15:2397–2412.

Diercks G, Larsen H, Steward F (2018) Transformative innovation policy: Addressing variety in an emerging policy paradigm. Research Policy. doi: https://doi.org/10.1016/j.respol.2018.10.028

Dignum M, Correljé A, Cuppen E, et al (2016) Contested technologies and design for values: The case of shale gas. Science and engineering Ethics 22:1171–1191
Dobbs R, Sawers C, Thompson F, et al (2014) Overcoming obesity: an initial economic analysis. McKinsey global institute

Dosi G, Llerena P, Labini MS (2006) The relationships between science, technologies and their industrial exploitation: An illustration through the myths and realities of the so-called ‘European Paradox.’ Research Policy 35:1450–1464

Duru M, Therond O, others (2015) Designing agroecological transitions; A review. Agronomy for Sustainable Development 35:1237–1257

Economic Affairs (1995) Derde Energienota, Tweede Kamer, vergaderjaar 1995–1996, 24 525, nrs. 1–2

Economic Affairs (1997) Duurzame energie in opmars. Actieprogramma 1997-2000

Edler J, Boon WP (2018) ‘The next generation of innovation policy: Directionality and the role of demand-oriented instruments’—Introduction to the special section. Science and Public Policy. doi: 10.1093/scipol/scy026

Elzen B, Geels FW, Green K (2004) System innovation and the transition to sustainability: theory, evidence and policy. Edward Elgar Publishing, Cheltenham and Northampton

EPA (1993) Fact sheet: respiratory health effects of passive smoking. Sacramento

Ergas H (1987) The importance of technology policy. In: Dasgupta P, Stoneman P (eds) Economic Policy and Technological Performance. Cambridge University Press, Cambridge, pp 51–96

ESIR (2017): Towards a Mission-Oriented Research and Innovation Policy in the European Union: An ESIR Memorandum: Executive Summary, Expert group on the Economic and Societal Impact of Research, European Commission, Brussels.

European Commission (EC) (2011) Horizon 2020 - The Framework Programme for Research and Innovation - Communication from the Commission

European Commission (EC) (2017): Interim evaluation of Horizon 2020. Commission staff working document, European Commission

European Commission (EC) (2018): Proposal for a Regulation of the European Parliament and of the Council, establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, COM/2018/435 final, European Commission, Brussels

European Parliament & European Council (2009) Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

Foray D, Mowery DC, Nelson RR (2012) Public R&D and social challenges: What lessons from mission R&D programs? Research Policy 41:1697 – 1702

Frenken K (2017) A complexity-theoretic perspective on innovation policy. Complexity, Innovation and Policy 35–47

Funtowicz SO, Ravetz JR (1993) Science for the post-normal age. Futures 25:739–755

Garud R, Karnøe P (2003) Bricolage versus breakthrough: distributed and embedded agency in technology entrepreneurship. Research Policy 32:277–300

Geels FW (2004) From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. Research policy 33:897–920
Gortmaker SL, Swinburn BA, Levy D, et al (2011) Changing the future of obesity: science, policy, and action. The Lancet 378:838–847

Grin J, Felix F, Bos B, Spoelstra S (2004) Practices for reflexive design: lessons from a Dutch programme on sustainable agriculture. International Journal of Foresight and Innovation Policy 1:126–149

Hajer MA, Pelzer P (2018) 2050—An Energetic Odyssey: Understanding ‘Techniques of Futuring’ in the transition towards renewable energy. Energy Research & Social Science 44:222–231

Head BW (2008) Wicked problems in public policy. Public policy 3:101

Henle K, Alard D, Clitherow J, et al (2008) Identifying and managing the conflicts between agriculture and biodiversity conservation in Europe—A review. Agriculture, Ecosystems & Environment 124:60–71

Hicks D (2016) Grand Challenges in US science policy attempt policy innovation. International Journal of Foresight and Innovation Policy 11:22–42

HM Government (2016) Childhood Obesity. A Plan for Action. 08/2016:13

Hoppe R (2011) The governance of problems: Puzzling, powering and participation. Policy Press

Hoppmann J, Huenteler J, Girod B (2014) Compulsive policy-making—The evolution of the German feed-in tariff system for solar photovoltaic power. Research Policy 43:1422–1441

Hyland A, Barnoya J, Corral JE (2012) Smoke-free air policies: Past, present and future. Tobacco Control 21:154–161.

JIIP et al. (2018a): Mission-Oriented Research and Innovation: Inventory and characterisation of initiatives. Final report. European Commission, Brussels.

JIIP et al. (2018b): Mission-Oriented Research and Innovation: Assessing the impact of a mission-oriented research and innovation approach. Final report. European Commission, Brussels.

Ison RL, Collins KB, Wallis PJ (2015) Institutionalising social learning: Towards systemic and adaptive governance. Environmental Science & Policy 53:105–117

Kaldewey D (2018) The Grand Challenges Discourse: Transforming Identity Work in Science and Science Policy. Minerva 56:161–182

Kern F, Kivimaa P, Martiskainen M (2017) Policy packaging or policy patching? The development of complex energy efficiency policy mixes. Energy Research & Social Science 23:11–25

Kuhlmann, S., Stegmaier, P, Konrad, K. (2019): The tentative governance of emerging science and technology: A conceptual introduction, Research Policy, doi.org/10.1016/j.respol.2019.01.006

Kuhlmann S, Rip A (2018) Next-Generation Innovation Policy and Grand Challenges. Science and Public Policy 1–7. doi: 10.1093/scipol/scy011

Kuhlmann S, Rip A (2014) Research policy must rise to a grand challenge. Research Europe 1–11

Lamine C (2011) Transition pathways towards a robust ecologization of agriculture and the need for system redesign. Cases from organic farming and IPM. Journal of rural studies 27:209–219

Lamy P, et al. (2017) Investing in the European future we want Report of the independent High Level Group on maximising the impact of EU Research & Innovation Programmes. Luxembourg

Lang T, Rayner G (2007) Overcoming policy cacophony on obesity: an ecological public health framework for policymakers. Obesity reviews 8:165–181
Latour B (1992) ‘Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts. In: Shaping Technology/building Society: Studies in Sociotechnical Change. MIT Press, pp 252–258

Levin K, Cashore B, Bernstein S, Auld G (2012) Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. Policy Sciences 45:123–152.

Loorbach D (2010) Transition management for sustainable development: a prescriptive, complexity-based governance framework. Governance 23:161–183

Mandel LL, Glantz SA (2004) Hedging their bets: Tobacco and gambling industries work against smoke-free policies. Tobacco Control 13:268–276.

May PJ, Jochim AE, Pump B (2013) Political limits to the processing of policy problems. Politics and Governance 1:104

Mazzucato M (2017) Mission-oriented innovation policy. UCL Institute for Innovation and Public Purpose Working Paper.

Mazzucato M (2018a) Mission-oriented innovation policies: challenges and opportunities. Industrial and Corporate Change 27:803–815

Mazzucato M (2018b) Mission-Oriented Research & Innovation in the European Union

Mazzucato M (2013) The Entrepreneurial State: debunking private vs. public sector myths. Anthem, London

Mazzucato M (2016) From market fixing to market-creating: a new framework for innovation policy. Industry and Innovation 23:140–156

Morgan K, Murdoch J (2000) Organic vs. conventional agriculture: knowledge, power and innovation in the food chain1. Geoforum 31:159–173

Mowery DC, Nelson RR, Martin BR (2010) Technology policy and global warming: Why new policy models are needed (or why putting new wine in old bottles won’t work). Research Policy 39:1011–1023

Nelson RR (1974) Intellectualizing about the moon-ghetto metaphor: a study of the current malaise of rational analysis of social problems. Policy Sciences 5:375–414

Newman J, Head BW (2017) Wicked tendencies in policy problems: rethinking the distinction between social and technical problems. Policy and Society 36:414–429

Oreskes N, Conway EM (2010) Merchants of Doubt.pdf. Bloomsbury Press, New York

Parkhurst J (2017) The politics of evidence: from evidence-based policy to the good governance of evidence. Taylor & Francis

RISE (2018) Mission-Oriented Research and Innovation Policy: A RISE Perspective, Research, Innovation and Science Policy Experts High-Level Group, European Commission, Brussels.

Rittel HWJ, Webber MM (1973) Dilemmas in a general theory of planning. Policy sciences 4:155–169

Roberts N (2000) Wicked problems and network approaches to resolution. International public management review 1:1–19

Roeser S (2011) Nuclear energy, risk, and emotions. Philosophy & Technology 24:197–201

Rogge KS, Reichardt K (2016) Policy mixes for sustainability transitions: An extended concept and framework for analysis. Research Policy 45:1620–1635.
Rotmans J, Loorbach D (2009) Complexity and transition management. Journal of Industrial Ecology 13:184–196.

SAE (2014) Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems J3016_201401, issued 2014-01-16

Sanderson FJ, Kucharz M, Jobda M, Donald PF (2013) Impacts of agricultural intensification and abandonment on farmland birds in Poland following EU accession. Agriculture, ecosystems & environment 168:16–24

Schor J (2016) Debating the sharing economy. Journal of Self-Governance & Management Economics 4:

Schot J, Steinmueller E (2016) Framing innovation policy for transformative change: Innovation policy 3.0. SPRU Science Policy Research Unit, University of Sussex: Brighton, UK

Schot J, Steinmueller WE (2018) Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy 47:1554–1567

Schuitmaker TJ (2012) Identifying and unravelling persistent problems. Technological Forecasting and Social Change 79:1021–1031.

Sengers F, Raven RPJM, Venrooij AV (2010) From riches to rags: Biofuels, media discourses, and resistance to sustainable energy technologies. Energy Policy 38:5013–5027.

SER (2013) Energieakkoord voor duurzame groei. Rapport Energieakkoord, Sociaal-Economische Raad

Shove E, Walker G (2010) Governing transitions in the sustainability of everyday life. Research Policy 39:471–476.

Smith A, Kern F (2009) The transitions storyline in Dutch environmental policy. Environmental Politics 18:78–98

Steward F (2012) Transformative innovation policy to meet the challenge of climate change: sociotechnical networks aligned with consumption and end-use as new transition arenas for a low-carbon society or green economy. Technology Analysis & Strategic Management 24:331–343

Stoate C, Báldi A, Beja P, et al (2009) Ecological impacts of early 21st century agricultural change in Europe – A review. Journal of Environmental Management 91:22–46

Surgeon General (1971) The Health Consequences of Smoking. Rockville

Surgeon General (1972) The Health Consequences of Smoking. Rockville

Surgeon General (1986) The health consequences of involuntary smoking. Rockville

Surgeon General (2006) The Health Consequences of Involuntary Exposure to Tobacco Smoke: a Report of the Surgeon General. Atlanta

Termeer CJAM, Dewulf A (2018) A small wins framework to overcome the evaluation paradox of governing wicked problems. Policy and Society:1–17. doi: 10.1080/14494035.2018.1497933

Termeer CJAM, Dewulf A, Biesbroek GR (2017) Transformational change: governance interventions for climate change adaptation from a continuous change perspective. Journal of Environmental Planning and Management 60:558–576

Thompson DF (1980) Moral responsibility of public officials: The problem of many hands. American Political Science Review 74:905–916

Turnpenny J, Lorenzoni I, Jones M (2009) Noisy and definitely not normal: responding to wicked issues in the environment, energy and health. Environmental Science & Policy 12:347–358
Ulnicane I (2016) “Grand Challenges” concept: a return of the ‘big ideas’ in science, technology and innovation policy? International Journal of Foresight and Innovation Policy 11:5–21

Van Bueren EM, Klijn E-H, Koppenjan JF (2003) Dealing with wicked problems in networks: Analyzing an environmental debate from a network perspective. Journal of public administration research and theory 13:193–212

Van de Poel I, Fahlquist JN, Doorn N, et al (2012) The problem of many hands: Climate change as an example. Science and engineering ethics 18:49–67

Van der Meer E (2017) Evolution versus revolution; incumbents and entrants shaping the roadmap for autonomous vehicles, Utrecht University. Utrecht University

Voss JP, Bornemann B (2011) The Politics of Reflexive Governance: Challenges for Designing Adaptive Management and Transition Management. Ecology and Society 16:

Walker G, Cass N (2007) Carbon reduction, ‘the public’ and renewable energy: engaging with socio-technical configurations. Area 39:458–469

Weber KM (2006) Foresight and adaptive planning as complementary elements in anticipatory policymaking: A conceptual and methodological approach. In: Reflexive governance for sustainable development. Edward Elgar Publishing, Cheltenham and Northampton, pp 189–221

Weber KM, Rohracher H (2012) Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive ‘failures’ framework. Research Policy 41:1037–1047

Weber KM, Andreescu L et al. (2018) Transitions at the Horizon: Perspectives for the European Union’s future research- and innovation-related policies. Final Report of BOHEMIA project. European Commission, Brussels.

Webster CWR (2009) CCTV policy in the UK: reconsidering the evidence base. Surveillance and Society 6:10–22

Webster CWR (2002) The diffusion, regulation and governance of closed-circuit television in the UK. Surveillance & Society 2:

Welsh BC, Farrington DP (2009) Public area CCTV and crime prevention: an updated systematic review and meta-analysis. Justice Quarterly 26:716–745

Wesseling JH, Edequist C (2018) Public procurement for innovation to help meet societal challenges: a review and case study. Science and Public Policy

Wesseling JH, Farla JCM, Hekkert MP (2015) Exploring car manufacturers’ responses to technology-forcing regulation: The case of California’s ZEV mandate. Environmental Innovation and Societal Transitions 16:87–105.

Widome R, Samet JM, Hiatt RA, et al (2010) Science, prudence, and politics: The case of smoke-free indoor spaces. Annals of Epidemiology 20:428–435.

Wieczorek AJ, Negro SO, Harmsen R, et al (2013) A review of the European offshore wind innovation system. Renewable and Sustainable Energy Reviews 26:294–306

Wolsink M (2000) Wind power and the NIMBY-myth: institutional capacity and the limited significance of public support. Renewable energy 21:49–64

World Health Organization (WHO) (2000) Obesity: preventing and managing the global epidemic. World Health Organization