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Transformative innovation policy: A systematic review

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ABSTRACT

This paper reviews the emerging literature on "transformative" innovation policy (TIP) in order to (1) identify unique TIP characteristics and the challenges they imply for policymakers throughout the policy cycle and (2) examine the literature's contribution to practical policymaking. We identify five main distinguishing TIP characteristics and analyse the literature's understanding of how they influence the policymaking process. The analysis shows that the literature discusses TIP-related challenges in all stages of the policy cycle but does not provide much guidance on how to address key cross-cutting policymaking challenges such as how to achieve broad stakeholder involvement, evaluate transformative outcomes, and build up dynamic policymaker capabilities. In order for TIP ideas to be implemented in real-life policymaking, TIP scholars, therefore, need to more explicitly consider the practitioners' perspective and develop concrete models, tools and guidelines that help policymakers address the identified challenges.

1. Introduction

There is an emerging literature discussing the limits and boundaries to governing socio-technical change for addressing grand challenges through innovation policy (Fagerberg, 2018; Kuhlmann and Rip, 2018; Mazzucato, 2018; Schot and Steinmueller, 2018). The literature draws heavily on past writings on innovation policy but also on what could be labelled as "environmental innovation policy" (Taylor, 2008), "sustainable innovation policy" (Foxon and Pearson, 2008), "challenge-led innovation policy" (Mazzucato et al., 2020; Raven and Walrave, 2018), "grand challenge programs" (Hayter and Link, 2020), "transformative innovation policy" (Steward, 2012), and "mission-oriented policies" (Foray, 2018b; Karo, 2018; Mazzucato, 2018). In this body of literature, some contend that we may still benefit from accumulated research on innovation policy to design and implement transformative policy (Fagerberg, 2018). Other authors suggest that a new type of policy approach is needed, one which departs from research on sustainability transitions (Schot and Steinmueller, 2018) or a newly developed mission-oriented framework (Mazzucato, 2018).

For this literature review, we connect two main emerging literatures on transformative innovation policy: one which draws on innovation and transition studies and one which builds on the missions-oriented policy framework (Diercks et al., 2019). Despite having different starting points, these two streams share multiple characteristics and have recently begun to move in the same direction conceptually. One common feature is that both are preceded by two earlier policy generations. The idea of mission-oriented policies stems from late 19th and early 20th century ideas on modernization and the "developmental state", but most famously from the military and space projects of the 1940s to 1960s in the US and major Western European economies (Kattel and Mazzucato, 2018). This latter mission-oriented approach partly overlapped with the dominating science and technology (S&T) innovation policy agenda of the mid-20th century. The innovation systems policy discourse emerged thereafter, pointing to the need of a more holistic and

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systemic approach (Freeman, 1987; Lundvall, 1992; Nelson, 1993). Under influence of various innovation system perspectives, the justification for policy intervention shifted towards systemic weaknesses rather than market failures, aiming at stimulating interaction and learning rather than simply plowing more money into R&D (Kline and Rosenberg, 1986; Weber and Rohracher, 2012). The mission-oriented perspective, however, did not adopt a systemic view on innovation, and the two streams have only recently begun to converge into a third-generation aimed at addressing societal challenges.

For addressing societal challenges, third-generation innovation policy integrates insights from the literature on sustainability transitions (Schot and Steinmueller, 2018) and combines a broader "understanding of the innovation process and a societal policy agenda" (Diercks et al., 2019, p. 883). Most importantly, the third generation calls for a new discussion on "directionality" (Diercks et al., 2019; Grillitsch et al., 2019), which implies that innovation should not be pursued for the sake of innovation or economic growth only but instead should be aimed at addressing important societal challenges. Similarly, third-generation mission-oriented policy has evolved from narrowly defined problems to a focus on grand challenges. This implies a shift from solving (technical) problems within a single governmental body to addressing challenges that require the collaboration of a multitude of actors (Kattel and Mazzucato, 2018). It is these third-generation transitions- and missions-oriented innovation policies that is the main interest of this paper. We place both these two perspectives under a common umbrella that we call *transformative innovation policy* (TIP).[1]

Under this umbrella, there seems to be agreement on two points: (1) that there is a need for knowledge on how innovation policy can be used to address grand challenges and (2) that practices and associated changes in administrative and organisational capacities of public organisations will be key for delivering such transformative policies (Karo, 2018). In the TIP literature, important steps have also been made towards formulating a new transformative innovation policy agenda and supporting the re-organisation of the innovation policy process. In this paper, we address the fact that the current understanding of what characterizes the transformative innovation policy paradigm, its roots and branches, and the actual contributions of the proposed frameworks on practical aspects of the policymaking process is rather unclear. One of many remaining questions is to which extent current writings contribute to our basic understanding of the policymaking process in terms of agenda-setting, policy design, legitimation, implementation, evaluation and policy learning and, thus, how ideas about different types of transformative innovation policies can be translated into policy practice (Brown, 2020; Uyarra et al., 2020). The lack of clear answers to this question is not insignificant. Kern and Rogge (2018) argue that incorporating policy processes into analytical frameworks applied towards transformative policy can bring several contributions, such as determining and shaping the elements of the policy mix for technological change, clarifying the dynamics resulting from interventions targeting socio-technical change, and fine-tuning policy recommendations (Edmondson et al., 2018; Hoppmann et al., 2014; Reichardt et al., 2017; Rogge and Reichardt, 2016). Nonetheless, early investigations indicate a skewed focus within the literature, with a bias toward individual policy instruments and policy mixes at the expense of outcomes of policy processes (Kern and Rogge, 2018) and, apparently, other parts of the policymaking process.

The purpose of this paper is to take stock of the current understanding of the specificities of transformative innovation policy and the challenges it involves throughout the policy cycle, and to examine the actual contributions of the received literature to practical policymaking. This is achieved through a critical and systematic review of the received literature on transformative innovation policy and related concepts.

We focus on two main aspects of the literature. First, we scrutinize the extant definitions and descriptions of transformative innovation policy in the literature in order to identify the key differences between TIP and previous generations of innovation policy. This results in the identification of a number of thematic areas that constitute the current understanding of the distinguishing characteristics of TIP. Second, we synthesize the contributions of the TIP literature for practical policymaking, i.e. what policymakers need to do differently to deal with transformative change, what challenges that implies and what frameworks they could use. For structuring this part of the review, we depart from the well-known policy cycle model (cf. Cairney, 2012; Howlett and Giest, 2013), which although it has been criticized for oversimplifying the policy process and underestimating its complexities (Cairney, 2012) describes the "reconstructed logic" of the policymaking process (Dunn, 2008) and remains the most classic way to study and organize policymaking (Cairney, 2012).

The rest of the paper is structured as follows. In Section 2, the method for conducting the literature review is outlined. Section 3 identifies and describes five main themes that synthesize the current understanding of the distinguishing characteristics of transformative innovation policy as compared with previous generations. In Section 4, the reviewed literature is analysed in relation to the policy cycle, and the most important TIP-specific challenges policy practitioners are likely to face in each step of the cycle are identified. Section 5 synthesizes these challenges and discusses to what extent they are addressed by the more concrete frameworks put forward in the literature. The paper ends with a concluding discussion in Section 6, which points at a number of gaps in the received literature and makes some suggestions on how to improve the practical relevance of transformative innovation policy research.

[1] The common understanding of what transformative innovation policy is will be explained in Section 3. It is also there we outline the common characteristics and differences that exist between the mission-oriented perspective and the innovation and sustainability transitions perspective. However, since it is beyond the scope of the paper, we do not systematically work out such differences in the remainder of the paper. Instead, we treat both underlying perspectives under the same umbrella of transformative innovation policy.

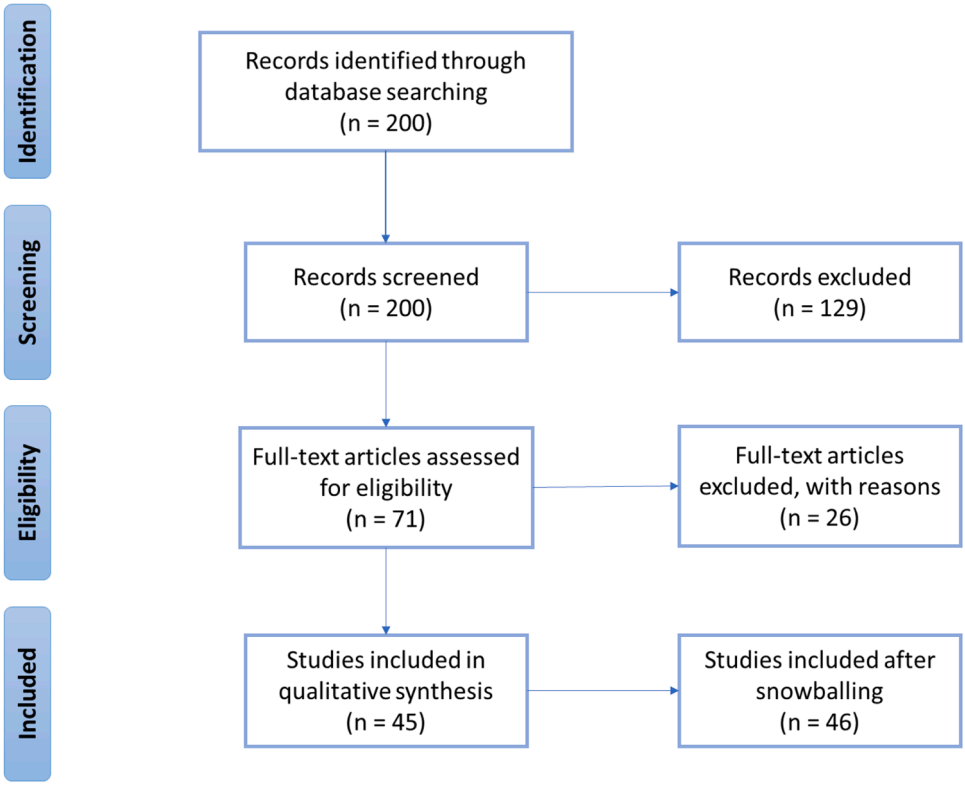

Fig. 1. Publications selection flow.

2. The review process

2.1. Article selection

In order to select a relevant number of articles to assess the characteristics of TIP in each stage and understand the challenges TIP imply in the different stages of the policy cycle, we used the guidelines provided by Petticrew and Roberts (2008) to conduct systematic literature reviews. We decided not to consider grey literature in this review, as our study focuses on exploring the current academic literature as a starting point for expanding future research.

The search was conducted in March 2019 using Elsevier's Scopus database, one of the largest databases of peer-reviewed academic publications. Based on an understanding of transformative change and socio-technical change, as framed in the literature of sustainability transitions (Geels, 2010), a number of search terms were generated in a brainstorming session.[2] We searched for all articles and articles-in-press in peer-reviewed academic journals with these search terms in the article title, abstract and keywords, covering publications from 1960 until March 2019 (all years included in the database). In this identification phase (see Figure 1), 200 documents were found.

In the second stage, all 200 abstracts were screened in order to exclude articles that were not relevant to the study. The following inclusion criteria were used: the article had to (1) address or attempt to conceptualize "transformative change" and (2) be written in English. Moreover, we used the following exclusion criteria: articles that (3) only referred to "transformative change" in passing or (4) did not bring any insights on innovation policy. This resulted in a selection of 71 articles to be fully read.

Each of the selected articles was read by one of the authors. In the third stage, the eligibility of the articles was assessed against the previously mentioned criteria. This led to the exclusion of 26 articles, resulting in 45 articles. We also identified one additional article via snowballing (Rogge and Reichardt, 2016), which we included in the review. Many of the other articles cited this article and based their own studies on it, and we decided that it was preferable to refer to the original work rather than to other authors' accounts of it. The final portfolio, therefore, consisted of 46 papers (see Appendix A for an overview).

[2] The following search query was used in Scopus: TITLE-ABS-KEY("innovat* polic*") AND TITLE-ABS-KEY(("transformat*") OR ("Transformat*" "Change*") OR (("Socio$technical change*") OR ("Socio$technical transition*")) OR ("Mission-oriented") OR ("grand challenge*" OR ("great" W/5 "challenge")) OR ("system innovat*")OR(("sustainab* transition*") OR ("transition*" W/5 "sustainab*"))).

2.2. Synthesis and analysis

The first step of the review of the selected articles was to identify a set of nine TIP characteristics, which were further aggregated into five thematic areas for further analysis. These themes summarized the main points raised by the literature regarding what is new in this emerging policy paradigm as compared with previous policy generations. In this part of the analysis, we also highlighted features that were specific to transitions- and mission-oriented innovation policy respectively. In the rest of the analysis, however, TIP was used as an umbrella term for both these approaches and characteristics that were common to both were later discussed in relation to the stages of the policy cycle.

In order to synthesize the findings, each author tabulated a set of papers in a shared table by describing them according to their research purpose, methods, frameworks, results and mention of the policy cycle stages. We adapted the generic policy cycle from Cairney (2012) and Howlett and Giest (2013) into six main stages: agenda setting, policy formulation, legitimation, implementation, monitoring and evaluation, and policy learning (see Section 4). Each author used the definition of each stage to determine whether an article referred to a specific policy cycle stage. More specifically, we checked if the article focused on a particular stage, i.e. discussed it more in detail, or just mentioned it in passing. Accordingly, we labelled the stages to which the articles were referring to as "main stages" and "secondary stages". We also made notes about the article's main arguments. In instances where an author was uncertain of which stages the article covered or whether they should be considered main or secondary stages, the others cross-read the article and discussed it together to reach a group consensus. Appendix A includes an overview of which article mentions which stage of the policy cycle and whether a stage is in main focus or not. Overall, the synthesis of the findings was discussed in various interactive exercises between the authors in order to make sure that we all had a common understanding. In the analysis of each stage in Section 4. TIP and the policymaking process: new approaches and challenges0, we mainly included the articles that focused on the respective policy stage, while articles that mentioned stages in passing were only included if they brought additional relevant arguments to the discussion. The main outcome of this analysis was the identification of a number of prominent challenges for policymaking in each step of the policy cycle, as mentioned in the literature. This was also done through an interactive process between all the authors, in which we first identified challenges mentioned in the literature and then discussed how they related to the five thematic areas and to the policy cycle. We called these "first-order" challenges, as they directly related to a thematic area and a specific stage of the policy cycle. These first-order challenges are discussed in Section 4 and summarized for each policy cycle stage.

We then proceeded to identify practical contributions for policy practitioners in relation to the identified challenges. In order to simplify this analysis, we grouped and thereby aggregated the first-order challenges into a set of nine "second-order" challenges, which transcended individual thematic areas and policy cycle stages. This was done by two of the authors, but discussed and validated by all authors.

Appendix B shows which first-order challenges were grouped together under each second-order challenge. We went through the reviewed literature to check for articles that provided guidance for policymakers on how to deal with these second-order challenges. We first identified all the articles that introduced a conceptual or analytical framework and then assessed whether the identified frameworks could be applied as policymaking tools. This assessment was based on two tentative criteria: usability and transferability, i.e. we included all frameworks that (a) we thought had a potential to be of some use to policymakers in relation to the identified challenges and (b) did not require significant adaptation to be used for a policymaking purpose. In total, we identified 14 frameworks from 17 articles (out of 46). Finally, we checked which second-order challenges each framework contributed to handling. We distinguished between frameworks that only "acknowledge" a particular challenge and frameworks that "address" that challenge. By acknowledge we mean that the framework recognizes a specific challenge, for example by mentioning the importance of it or including it in the analysis, but does not provide any guidance to handle it. For instance, in relation to the second order challenge 'coordination across policy domains and levels', Weber and Rohracher (2012), Bugge et al. (2017); Bugge et al. (2018) and Foray (2018a) all mention policy coordination as a potential transformative failure (i.e. as a rationale for policy intervention). However, they do not provide any clear advice on how to achieve coordination (or even diagnose such a failure).[3] Of course, this approach builds on the authors' subjective judgement, and we fully acknowledge that a different reader may come to a somewhat different conclusion so that our assessment may be interpreted as either too conservative or too generous. It should also be noted that frameworks can still be practically useful in other ways even if they do not address the identified challenges.

3. Characteristics of transformative innovation policy

Mission-oriented and transitions-oriented innovation policy can be seen as evolving largely in parallel but with similar agendas. For instance, Diercks et al. (2019) highlight that past innovation policy paradigms, such as the science and technology policy paradigm, had an economic and social agenda and this has also been a feature of mission-oriented research since the beginning of the 20th century. When it comes to innovation systems research, though, the focus moved from missions to the conditions necessary to enable innovation in general. Hence, less attention was directed at strategic priorities and broader social issues, but there now seems to be increasing convergence between the two streams around the so-called grand societal challenges. Indeed, Mazzucato (2018) and Schot

[3] It should be noted that our research scope is strictly focused on the articles and frameworks we identified in the systematic review. This implies that some of the gaps we identify might have been treated in other streams of literature or in articles published after our review was conducted. This also refers to the practical contributions. We are aware that some of the frameworks have evolved and been applied and developed further since our review, but it was out of our scope to systematically trace their development in order to see if their practical usefulness has improved over time.

Table 1
Main characteristics of transformative innovation policy.

Common characteristics	Transitions-oriented policy	Missions-oriented policy
Grand challenges and inclusive growth	Grand challenges as a new, broader goal for policy	
	Shift from a technology focus to behavioural and social change at the system level	
	Shift in the innovation agenda to focus on socio-technical transitions	Focus on missions (either well defined or "open-ended")
Directionality	Set a clear direction of change	
	Lack of directionality as a failure	Targeted, measurable and time-bound missions
	Bottom-up approach to complement top-down policies	Top-down when defining missions; bottom-up when selecting solutions
Multi-faceted policy intervention	Need for a more varied and complex set of policy instruments	
	Policy mixes, including policies for regime destabilisation	Design principles for addressing Grand Challenges
Multiple actors and global networks	Involvement of a broader set of actors	
	Emphasis on the diversity of opinions	Picking the willing
Multi-level governance	"Tentative governance"	
	Policy coordination and reflexivity failures	Negotiation of open-ended missions

and Steinmueller (2018) both acknowledge that third-generation innovation policy is different from past generations in this respect – regardless of whether the previous generation is policy focused on achieving narrowly defined missions (as in the former) or growth-oriented STI policy (as in the latter). Our review shows that these new generations share a number of key distinguishing characteristics (as summarized in Table 1.), even though they sometimes approach the same issue from different angles. In the following, we discuss each of these common characteristics while highlighting relevant differences and commonalities between the two approaches as we go along.

3.1. Grand challenges and inclusive growth

Innovation policy is increasingly being reoriented towards addressing "grand challenges" (Amanatidou et al., 2014). Challenges such as those presented in the 2015 Lund Declaration, the Paris Agreement, and the United Nations Sustainable Development Goals (SDGs) bring new opportunities for STI policy (Schot and Steinmueller, 2018). Reflecting upon that, STI and mission-oriented policy literature are both amidst a shift towards a new frame or generation that is directed at broader environmental and social concerns, such as climate change, aging societies, degradation, public health, security, energy, mobility, etc. (Alkemade et al., 2011; Amanatidou et al., 2014; Bugge et al., 2018; Cagnin et al., 2012; Coenen et al., 2015a; Giuliani, 2018; Raven and Walrave, 2018; Schot and Steinmueller, 2018). More specifically, the transformative policy agenda shifts the focus from a mainstream macroeconomics perspective to that of socio-technical transitions (Steward, 2012). Various initiatives at both global and national levels are being designed to address a number of societal challenges. For example, the EU Horizon 2020 and the European Green Deal aims at addressing challenges such as the transition towards a low-carbon and inclusive economy (Schot and Steinmueller, 2018). The Global Covenant of Mayors for Climate and Energy formed in 2016 is an international effort that brings together cities and local governments from 121 different countries to meet the Paris Agreement objectives (Diercks et al., 2019). At the national level, the Strategic Innovation Programmes (SIPs) in Sweden follow the societal challenge logic for policy and targets different sectors, e.g. forestry, chemicals and energy (Grillitsch et al., 2018).

Grand challenges are 'wicked', i.e. characterized by complex interdependencies, necessitating solutions which radically replace unsustainable practices and go beyond technological advancements to include behavioural and cultural change as well as social innovation (Amanatidou et al., 2014; Coenen et al., 2015a). While this is acknowledged also by proponents of the new generation of missions-oriented policy (Cagnin et al., 2012; Foray, 2018b; Mazzucato, 2016), other authors argue that addressing grand challenges is much more complex than the next generation of mission-oriented policy, and that such challenges rather should be seen as "open--ended missions", i.e. missions that induce system transformation (Edquist and Zabala-Iturriagagoitia, 2012; Kuhlmann and Rip, 2018).

3.2. Directionality

The focus on solving grand challenges implies that transformative innovation policy has a clearer direction than in most innovation system-based policy frameworks. Consequently, lack of directionality is considered a new rationale for policy intervention in the transitions-oriented policy literature (cf. Weber and Rohracher, 2012). In the missions-oriented policy framework, directionality was addressed already by previous generations, but in different contexts (Kattel and Mazzucato, 2018). Earlier generations focused on missions of national advancement (1st generation) and national security and technological arms races (2nd generation), whereas the third-generation aims at addressing grand challenges, which implies going beyond the national level to include effort at all levels of governance (Amanatidou et al., 2014).

While thus agreeing on the importance of directionality, the two streams differ somewhat in how they define direction and the role of policy in setting that direction. In the transitions-oriented notion of directionality, the role of policy is described in terms of identifying a portfolio of "acceptable development paths" in a situation where there is little consensus over the direction a transition should take, i.e. directionality failure (Weber and Rohracher, 2012). It is emphasised that new technologies and solutions are developed from the bottom-up in "niches", although more top-down policy interventions might be necessary to exert enough pressure

on established "regimes" to allow these novelties to break through (Kivimaa and Kern, 2016; Steward, 2012). In contrast, the missions-oriented policy literature departs from pre-defined missions that are supposed to be well defined, measurable and time-bound (Mazzucato, 2018). This implies that mission-oriented policy starts from the top-down, from missions defined "outside" the system it is supposed to change. It is these chosen missions that define the direction, and policy is then used to tilt the "playing field" in the direction of the desired goals (Kattel and Mazzucato, 2018; Mazzucato, 2018). However, also in mission-oriented policy, the process of selecting multiple solutions involves a more bottom-up approach in which spaces for contestation and adaptability need to be created (Kattel and Mazzucato, 2018). Along the way, these solutions might either fail or need to be adjusted in order to reach the mission's expected outcome (Mazzucato, 2018).

3.3. Multi-faceted policy intervention

Both streams emphasise the need for a more varied and complex set of policy instruments to address grand challenges. In the missions-oriented policy approach, this discussion is limited to acknowledging the need for both "horizontal" (i.e. sector-neutral) policies and "vertical" policies targeting a certain sector or cross-sectoral societal mission, and the importance of designing policy principles to support the policymaking process of innovation-driven growth (Foray, 2018a; Mazzucato, 2018). In contrast, the review of the transitions-oriented policy shows a great influence of the policy-mix concept, which emerged already in an innovation system policy context to reflect different types of policy measures, domains, and governance levels (Bugge et al., 2018). [4] This was extended by Rogge and Reichardt (2016), who stress that policy mixes are also comprised of policy strategy, policy processes and characteristics. Many authors argue that a comprehensive policy mix for transformative change should combine supply-side and demand-side policies (Diercks et al., 2019; Rogge and Reichardt, 2016; Schot and Steinmueller, 2018; Steward, 2012). Moreover, it should not only include support to niche experiments but also measures to destabilise existing regimes (Kivimaa and Kern, 2016), including the main political institutions and cultures (Johnstone et al., 2017). Schot and Steinmueller (2018) also highlight that any new policy initiative must navigate pre-existing policies, and it is crucial to find ways to productively layer new policies.

3.4. Multiple actors and global networks

Both approaches emphasise that in order to address a wider social agenda, a broader set of actors need to be involved (Diercks et al., 2019; Steward, 2012). Kuhlmann and Rip (2018) point out that actors play an important role as assemblers and re-assemblers of socio-technical configurations, which opens up the possibility for new constellations of actors to emerge and shifts the focus away from government agencies and "triple helix" constellations to a diversity of "social" partners, such as public authorities, civil society and economic operators (Schot and Steinmueller, 2018). Moreover, Grillitsch et al. (2019) argue that global actor networks, i.e. intergovernmental organisations, transnational cooperation, states and civil society, have an important role to play. Some authors also acknowledge the need for new modes of governance that are able to involve multiple actors in the policymaking process while considering a democratic and transparent process (Cagnin et al., 2012; Fagerberg, 2018; Kuhlmann and Rip, 2018).[5] From a mission-oriented point of view, the involvement of multiple actors from different disciplines, industries and types of partnerships is motivated mainly in a later stage, when solutions to identified missions are to be found, although there is also a need to share risks and rewards between the public and private sectors in the design phase (Mazzucato, 2018). However, whereas the missions-oriented policy literature argues that participants should be "picked" based on their willingness to engage with a particular mission (Mazzucato, 2018), the transition-oriented policy literature puts more emphasis on selecting participants reflecting a diversity of stakeholder opinions and opening up for public debates, negotiations and conflicts over alternative pathways (Schot and Steinmueller, 2018).

3.5. Multi-level governance

When it comes to TIP interventions, the level of efforts should consider all levels of governance, i.e., local, regional, national and international (Amanatidou et al., 2014; Steward, 2012). This has also been evident in recent programmes targeting grand challenges, which address levels other than just the local or national, as mentioned before. Both streams rely on the notion of "tentative governance", although this notion has been developed furthest in relation to transitions-oriented policy. According to Kuhlmann and Rip (2018), addressing grand challenges involve open-ended missions that will be contested and negotiated and will evolve over time. Hence, a meta-approach to governance is needed, which is more "provisional, flexible, revisable, dynamic and open … [and] include [s] experimentation, learning, reflexivity, and reversibility" (Kuhlmann and Rip, 2018, p. 450). This links governance to experimentation, which in the sustainability transitions literature is seen as a mean to implement coordination. Moreover, this implies that an inability to involve actors in a process of self-governance can lead to both reflexivity and coordination failures (Weber and Rohracher, 2012). Furthermore, Schot and Steinmueller (2018) stress the importance of open-ended coordination, which refers to the interaction between different policy domains (more specifically science-technology-innovation (STI) policy, sectoral policy and other cross-sectoral domains (such as tax policy)) and policy levels in building the pathways of transformative change. In an attempt to

[4] One of the earliest articles introducing policy mixes to the transitions field was Kern and Howlett's (2009) "Implementing transition management as policy reforms: a case study of the Dutch energy sector" in *Policy Sciences*.

[5] While some authors within the reviewed literature acknowledge the importance of politics and democracy in transitions, they do not go in depth in such a discussion. Interested readers are referred to, among others, Voß et al.'s special issue in *Policy Sciences* (Voß et al., 2009).

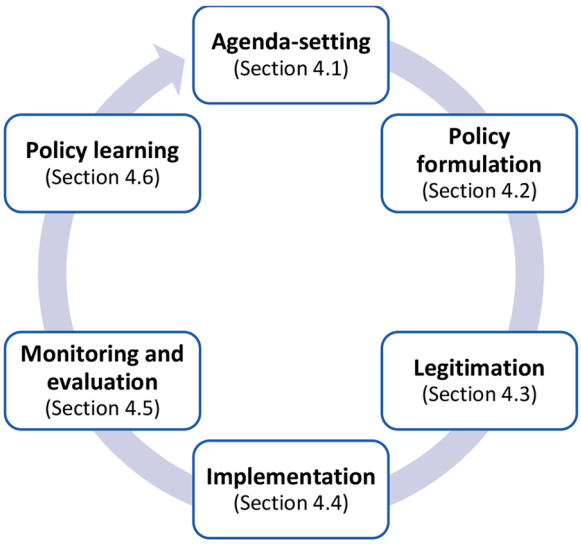

Fig. 2. The generic policy cycle. (Source: adapted from Cairney (2012) and Howlett and Giest (2013)).

Table 2
Summary of findings related to agenda-setting.

Themes	TIP-specific stage characteristics	Identified challenges
Grand challenges	Different policy objectives (societal challenges rather than economic growth)	Reconciling perceptions on the narrowness/breadth of innovation perspective
Directionality	New rationales for innovation policy	Translating Grand challenges into concrete actionable problems Coordinating directionality between multiple-actors and global networks Lack of shared vision and insufficient regulation to guide change
	Involvement of new constellations of actors	Promoting institutional entrepreneurship directed towards socio-technical change
Multi-faced policy intervention	Broader set of policy domains	Coordinating directionality between multiple-actors and global networks
Multiple actors	Role of incumbent actors	Undue influence from incumbent actors

synthesize these conceptual developments, Bugge et al. (2018) introduce the concept of "governance mix" (in analogy to the policy mix concept discussed in the previous section) and argue for meta-governance through a mix of different (bottom-up and top-down) governance modes in an attempt to "orchestrate" the transformative process.

4. TIP and the policymaking process: new approaches and challenges

To structure our analysis of the contributions of the TIP literature to our understanding of the policymaking process, we use the policy cycle model. It essentially breaks down the policy process into stages in order to, for example, helps identify possible styles of activity and potential bottlenecks throughout the process (Howlett and Giest, 2013). Even though this model has been criticized for oversimplifying the complexities of the policy process and taking policymaking as being fluid and cyclical, it is currently the most classic way to study and organize policymaking and hence serves as an insightful analytical approach (Cairney, 2012). It describes the "reconstructed logic" of the policymaking process rather than the "logic-in-use" by policymakers (Dunn, 2008) and is, thus, best thought of as a heuristic device that can be used to describe and analyse policy processes (Cairney, 2012).

There are many variations of the policy cycle model in the literature (Cairney, 2012). We have opted for a six-stage model, which integrates insights from two main sources: Howlett and Giest (2013) and Cairney (2012) (see Figure 2). In the following, we first define each step and then discuss the TIP literature's understanding of how the step is different in TIP (as compared with previous policy generations), the challenges it identifies in relation to each step and the suggestions and frameworks it presents to guide policymakers when dealing with transformative change. Since the policy cycle model does not explicitly consider feedback loops, we will take note of such interrelationships when we discuss the affected stages.

4.1. Agenda-setting

Agenda-setting involves the identification of problems that deserve the attention of policymakers (Cairney, 2012). It requires

policymakers to prioritize between all the different matters of concern that are pressing for their consideration (Howlett and Giest, 2013) and to get information about the causes of the problem and define the desired outcome of a policy intervention (Dunn, 2008). From the policy literature, the agenda-setting stage can be described in terms of three main dimensions: policy objective (the overall aims of the policy), policy domain(s), and policy logic (how innovation policy is rationalized) (Diercks et al., 2019). In describing this stage, we will reflect on these three dimensions, when relevant. The main differences and challenges related to agenda-setting will be discussed in the context of the TIP- themes identified in Table 1 and are summarized in Table 2.

Beginning with grand challenges and inclusive growth, transformative innovation policy opens up the policy agenda and brings a broader understanding of societal goals. In this way, there is a shift in relation to *policy objectives* from previous approaches of innovation policy and TIP. Diercks et al. (2019) argue that previous approaches focus either on a purely economic agenda, which views innovation as being essentially good as it leads to economic competitiveness and growth or on a narrow view on the societal agenda, which is motivated mainly by national strategic priorities (e.g. national security). As described in Section 3, most authors point out that the ultimate aim of transformative innovation policy is to address societal problems or grand challenges, such as those highlighted in the Paris Agreement and the SDGs (Alkemade et al., 2011; Amanatidou et al., 2014; Cagnin et al., 2012; Diercks et al., 2019; Grillitsch et al., 2019; Kattel and Mazzucato, 2018; Kuhlmann and Rip, 2018; Mazzucato, 2018; Robinson and Mazzucato, 2019; Schot and Steinmueller, 2018; Steward, 2012; Weber and Rohracher, 2012). This implies that economic, environmental, and social objectives are interrelated and have to be considered together (Crespi, 2016). Moreover, it also calls for an inclusive concept of growth, which acknowledges that both the risks and rewards of innovation and economic growth should be distributed fairly in society (Mazzucato, 2016). The TIP literature also emphasises that innovation does not always bring good outcomes and that many of the societal challenges faced today are a direct or indirect result of past innovations (Alkemade et al., 2011; Amanatidou et al., 2014; Diercks et al., 2019; Foxon and Pearson, 2008; Soete, 2019; Steward, 2012). Hence, one of the biggest challenges related to the notion of Grand challenges is the need to reconcile the perception of the innovation process in terms of what should be included, i.e. how narrowly or broadly it should be defined (Diercks, 2018; Diercks et al., 2019). This reconciliation process is of course a system-wide process, but as Diercks (2018) exemplifies it also includes specific organisations, such as the OECD, which have the capacity to influence the policy debate.

In terms of *policy logic*, several of the authors argue that, in the context of grand challenges, we need a broader view on the underlying rationales for innovation policy, moving from market and innovation system failures to more comprehensive frameworks that better reflect the characteristics of transformative innovation processes (Chicot and Matt, 2018; Foray, 2018b; Grillitsch et al., 2019; Kivimaa and Kern, 2016; Mazzucato, 2016; Mazzucato, 2018; Robinson and Mazzucato, 2019; Schot and Steinmueller, 2018; Weber and Rohracher, 2012). Many authors introduce new "transformative failures", which include new rationales – not limited to market or system failures (cf. Woolthuis et al., 2005) – to justify policy intervention in relation to a broader scope of the policy agenda. These failures differ in the studied literature and can include, for instance, directionality, demand articulation, policy coordination, and reflexivity failures (Weber and Rohracher, 2012); and demand-side, supply-side, and user-supplier interactions failures (Chicot and Matt, 2018).

'Directionality' failure, in particular, relates to the lack of direction and priorities of the innovation process towards transformative change and calls for new agenda-setting routines (Kuhlmann and Rip, 2018; Weber and Rohracher, 2012). According to Robinson and Mazzucato (2019, p. 938), "fixing directional failures require articulation of broad societal and socio-economic challenges for which concrete actions can be supported to contribute towards desired transformative change". As such, one of the main challenges related to directionality remains in translating grand challenges into concrete problems (Robinson and Mazzucato, 2019).

Adding to that and linked to the theme 'multiple actors', Kuhlmann and Rip (2018) point out that directionality implies including new constellations of actors in agenda-setting, in which the government has a central role. This includes, for instance, institutional entrepreneurs who are actors that initiate and engage in the changing process and hence are fundamental in providing directionality (Grillitsch et al., 2019). However, this also brings new challenges to policymaking, such as promoting institutional entrepreneurship towards the transformation of socio-technical regimes and coordinating directionality between multiple stakeholders in the process of agenda-setting (Grillitsch et al., 2019; Weber and Rohracher, 2012). Moreover, directionality implies building shared visions and for that, power and agency play an important role. Therefore, two additional challenges to directionality are the ability (or lack thereof) to build a shared vision regarding the direction of change, as well as the lack of regulations and standards to guide this process (Weber and Rohracher, 2012). A discussion around the role of different stakeholders in relation to these challenges, however, has not yet been addressed.

The involvement of 'multiple actors' also brings other challenges, such as undue influences from incumbent actors (Schot and Steinmueller, 2018). In this way, established actors in the socio-technical systems that are the object of a transformation might attempt to push their own agenda by influencing policymakers (Johnstone et al., 2017; Mazzucato, 2016). Based on an analysis of the UK energy sector, Johnstone et al. (2017) show how incumbents use a range of different strategies to influence agenda-setting, for example by modifying the policy objective towards national security ("securitization"), hiding the full costs of the regime ("masking"), making old technologies look new or innovative ("reinvention"), or gaining political influence ("capture"). This highlights the need to put regime destabilisation on the political agenda (Kivimaa and Kern, 2016) and to shift focus from economic growth to phasing out unsustainable regimes (Alkemade et al., 2011).

When it comes to the impact of 'multi-faceted policy interventions' in agenda setting, several authors highlight that a broader societal policy agenda encompasses several *policy domains* apart from economic and industrial policies, such as energy, health, labour, agricultural, food security, environmental and climate change policy (Cagnin et al., 2012; Coenen et al., 2015a; Crespi, 2016; Diercks et al., 2019; Scordato et al., 2018). Moreover, some of the authors argue that there is a need for innovation policy to move beyond stimulating technological change and instead focus on system innovation (Schot and Steinmueller, 2018). For example, Steward

Table 3
Summary of findings related to policy formulation.

Themes	TIP-specific stage characteristics	Identified challenges
Grand challenges and inclusive growth	Addressing wide societal objectives	Targeting multiple objectives Stimulating both technical and non-technical solutions
Multi-faceted policy intervention	Emphasis on the context and complexity of the policy formulation process	Stimulating experimentation and demand with a multitude of instruments Differentiating support based on technology maturity Finding the right "granularity" of policy Destabilising existing locked-in socio-technical systems Combining 'horizontal' and 'vertical' policies
	Depart from the processes of drift, conversion and layering rather than purposeful design	Identifying and aligning the "right" combination of instruments Coordinating policy through mutual adaptation
Multi-level governance	Innovation of new governance models to circumvent policy fragmentation	Handling fragmentation across policy areas and governance levels. Recognizing key actors, such as regions
	Strengthen the role of the state	Ensuring autonomy of state throughout the formulation process Strengthening domain knowledge and analytical capacity

(2012) points out that while innovation policy practice remains focused on individual technologies, transformative policies should be embedded in other social domains, such as household living and personal mobility, which involves different technologies, multiple actors, and several social and behavioural innovations. One main challenge related to this broadening of policy domains is the greater need for both vertical and horizontal coordination between different policy areas and levels of government (Weber and Rohracher, 2012). Such coordination challenges are also reported in several empirical studies (cf. Bugge et al., 2017; Coenen et al., 2015b).

4.2. Policy formulation

Policy formulation refers to the identification of potential solutions to the problems raised in the previous stage, considering their cost, feasibility and effects, and the selection of policy instruments (Cairney, 2012; Howlett and Giest, 2013). This requires knowledge about the expected consequences of different instruments as well as value judgements regarding the utility of different possible outcomes (Dunn, 2008). It is a juncture point where agendas are developed into actionable proposals.

From a transformative innovation policy perspective, policy formulation is not a straightforward process where one simply can make a cost-benefit analysis of different policy instruments and assess their various impacts. The dominating idea in the literature is instead that formulating policies in relation to 'grand challenges and inclusive growth' involves combining a wide set of instruments (i.e. multi-faceted policy interventions) in order to address multiple wider societal objectives (Diercks et al., 2019; Fagerberg, 2018). This, hence, goes beyond simple heuristics such as the "one policy target, one policy instrument" principle (described as the Tinbergen's Theorem by Foray (2018)). However, in this respect, the literature has difficulties moving beyond providing simple heuristics and formulation of challenges such as to "target multiple objectives" or "stimulate both technical and non-technical solutions" (Amanatidou et al., 2014; Fagerberg, 2018).

In contrast, the need to formulate policies that build capacity for innovation and transformative change is discussed at some length (see Table 3 for a summary). For example, Schot and Steinmueller (2018) argue that it is crucially important that potential solutions stimulate experimentation and demand articulation in niches outside of the established regime pressures. Similarly, Foray (2018a) stresses the need to use "non-neutral" policies to focus on activities that have the potential to transform sectors or establish new ones. This implies providing support for a variety of processes behind niche formation (Kivimaa and Virkamäki, 2014). Similarly, Foray (2018a) points to a set of principles that should guide the policy formulation process, such as securing human capital and demand for specific R&D, couple innovation and diffusion, and recognizing the experimental nature of policy. Along the same lines, Taylor (2008) illustrates that it was the multitude of instruments, which went beyond traditional "push" and "pull" policies, that created favourable conditions for the development and diffusion of solar power in California. In addition, Foxon and Pearson (2008) argue that instrument choice needs to take the maturity of the technology into account. If one aims to radically reduce emissions, immature technologies may need a different type of support compared with mature alternatives (Foxon and Pearson, 2008). In this respect, Edquist and Zabala-Iturriagagoitia (2012) and Chicot and Matt (2018) emphasise the role of Public Procurement for Innovation (PPI), which they argue can be used together with other instrument types in order to both stimulate variation and scale up new and promising technologies.

It is also argued that policy needs to contribute to a process of destabilisation of existing locked-in socio-technical systems (Kivimaa and Kern, 2016; Rogge and Reichardt, 2016). Here the literature emphasises the potentially very strong resistance from those who benefit from the current systems (Johnstone et al., 2017; Rogge and Reichardt, 2016; Schot and Steinmueller, 2018). Overcoming such regime pressures requires policy to connect different sectors, regimes, and niches (Raven and Walrave, 2018; Raven and Verbong, 2009), and to combine "horizontal" (international-national-regional) policies with "vertical" policies that cut across policy domains, national boundaries and industrial sectors (Robinson and Mazzucato, 2019). While this is an interesting contextualization, which emphasises the complexity of the policy formulation process, this literature provides very limited practical direction to those interested in policy formulation and selection of appropriate instruments.

Table 4
Summary of findings related to legitimation.

Themes	TIP-specific stage characteristics	Identified challenges
Multiple actors and global networks and Multi-level governance	Legitimacy is an embedded property in governance processes which requires the activation of key stakeholders	Creating learning platforms Activating stakeholders with a clear transition agenda Avoiding "destructive recreation"
	Legitimacy of policy mixes	Handling changing legitimacy over the course of implementation and time
	Translation of key ideas in policy organisations	Developing appropriate governance structures Translating transformative ideas into policy practice in dominating policy organisations

The literature notes that the policy formulation process is dominated by different forms of "drift" and "conversion" processes, involving existing policies, rather than the purposeful design of entirely new mixes. Such layering of new policies on top of existing ones can lead to inconsistencies (Peng and Bai, 2018; Schot and Steinmueller, 2018). It is furthermore argued that an under-appreciation of policy complexity may lead to conclusions in which increased coordination is suggested as a primary intervention, implicitly assuming a single level of governance managed by a fully rational policymaker. In contrast, Crespi (2016) argues that coordination can at best be the outcome of a mutual adaptive process between actors and systems. In this context, the analysis of interactions and trade-offs between policy instruments and their impacts on the ultimate policy objectives is crucial for fruitfully developing and operationalizing the concepts of policy mix and policy coordination. Policy alignment should, therefore, be the focus for policy formulation rather than the design of individual instruments (Crespi, 2016).

With regard to the theme of 'multi-level governance', Fagerberg (2018) and Amanatidou et al. (2014) argue that there is a need for innovation in governance models in order to circumvent the discontinuity and fragmentation across different policy areas and governance levels (regional, national, international), which forms an obstacle for policy formulation in relation to grand challenges. Similarly, Robinson and Mazzucato (2019) argue that mission-oriented innovation policies require new government approaches which are formulated around these missions. Part of this is to recognize the strength of various types of governmental actors to participate in the formulation process. Steward (2012), for example, argues that regional actors play a key role since they are practice-oriented, quick to experiment, and learn from various policy experiments. Similarly, Edquist and Zabala-Iturriagagoitia (2012) argue that certain types of public procurement for innovation might be more effective at a local level.

As a consequence, the capacity of different types of government actors to participate in policy formulation processes becomes a salient feature in the literature. For example, Fagerberg (2018, p. 1570) argues that "it is vital that the autonomy of government is retained through appropriate policy design" and Schot and Steinmueller (2018, p. 1565) argue that there is a need to increase the capacity of policy in the formulation phases since there may be "incompatibility between the framings which policy actors will have to navigate." Kattel and Mazzucato (2018), Janssen (2019) and Kuhlmann and Rip (2018) all stress the importance of policy having domain knowledge and analytical capacity. Compared with designing single, "technology-neutral" instruments, TIP requires policy-makers to have deep knowledge about the context in which they operate (Foxon and Pearson, 2008; Kattel and Mazzucato, 2018). Another challenge is to find the right "granularity" of policy, which needs to be more refined than targeting sectors but coarser than individual entities (Foray, 2018a). This is also stressed by Kivimaa and Virkamäki (2014), who argue that coherent policy mixes need to be created in relation to selected technology-specific niches rather than the system as a whole.

Finally, since policy tends to have very limited foresight, it is also argued that evaluation and learning must be built-in already in the formulation phase so that individual policies can be adapted along the way (Amanatidou et al., 2014; Hoppmann et al., 2014; Steward, 2012). This will be explored further in Section 4.5 on monitoring and evaluation and Section 4.6 on policy learning.

4.3. Legitimation

In the legitimation stage, policymakers make sure that the chosen course of action has support among relevant stakeholders, for example through consultations with legal experts, interest groups or the general public (Cairney, 2012).

There seems to be general agreement in the reviewed literature that the special character of transformative innovation translates into new challenges for creating legitimacy for new policy initiatives and activities. The reviewed literature, mainly, departs from the two general themes of multi-level governance, multiple actors and global networks when discussing legitimacy. The general view is that legitimacy is created through stakeholder interaction in a multi-level governance mode, which also implies that splitting the discussion below into the two themes is not meaningful (see Table 4).

To begin with, Schot and Steinmueller (2018), Mazzucato (2018), Kuhlmann and Rip (2018) suggest that legitimacy for transformative innovation policies is created through a broad stakeholder involvement where the relevant actor groups in society are activated and motivated to contribute to the transitions' agenda. In the view of Kuhlmann and Rip (2018) and Schot and Steinmueller (2018), the basis for the legitimation process is experimentation and learning, where it is argued that explicit learning platforms may have to be created for increasing the legitimacy of actions directed towards addressing Grand Challenges.

It is furthermore argued that "guidance is effectuated embedded in evolving social ordering when there is some legitimacy" (Kuhlmann and Rip, 2018, p. 448). This implies that a next generation of innovation policy cannot just be considered in its own right, as another game between policy actors and policy subjects" (Kuhlmann and Rip, 2018, p. 450). From this perspective, legitimacy is,

Table 5
Summary of findings related to implementation.

Themes	TIP-specific stage characteristics	Identified challenges
Multi-faced policy intervention	Implementation structures at different governance levels	Building sufficient implementation structure and capacity
Multiple actors	Stakeholder involvement in the innovation process	Handling conflicts of interest and power struggles Involving stakeholders Building trust, aligning interests, and encouraging collaboration between different stakeholders
Multi-level governance	Different modes of governance	Coordinating policy between different levels of government Understanding constraints of the political system and cultural context Balancing trade-offs between strong leadership and guidance required for the transition process

thus, an embedded property in governance processes and where the creation of legitimacy takes activation of stakeholders with a clear transition agenda rather than existing regime actors. Mazzucato (2018) addresses the creation of legitimacy in a slightly different way and link the legitimacy process more clearly to the goals and missions that are at focus. Mazzucato (2018) also argues that legitimacy for transformative innovation policy is created by activating "the willing" and not necessarily by trying to activate or convince those that are sceptical. The perspective thus puts the focus on the challenge of activating the "right" stakeholders and avoiding a "destructive recreation" in which the lack of legitimacy of the current transformative discourse may move incumbents to develop strategies that endanger current niche experimentations (Johnstone et al., 2017). A clear gap which we identify is that, although mentioned as important, the literature gives few clues as to how legitimacy is created in practice, i.e. how "learning platforms" can be designed, how the willing are identified and activated and how destructive recreation can be avoided.

Another set of studies depart more from the 'policy mix' literature and combines it with a technological innovation systems perspective (cf. Bergek et. al., 2008) to study the relation between policy mixes and the development of new technologies as well as industries. The combination allows for bottom-up studies on how legitimation (as well as other key innovation processes) are strengthened depending on the design of the policy mix (Janssen, 2019; Kivimaa and Kern, 2016; Scordato et al., 2018). Although the policy mix is assessed in the above studies, the formation of legitimacy of the policy mix is typically not a focus of the analysis and there is a clear lack of studies that explicitly analyse the formation and changing nature of legitimacy in the formation and implementation of various policies. A telling exemption is, however, Hoppmann et al. (2014), who draw on the case of the development of solar policy in Germany and effectively illustrate the process in which the legitimacy of policy changes with implementation and over time. The feedback from stakeholder in the implementation over time give rise to something that is called "compulsive policymaking", in which the success of certain policy initiative gives rise to new policy challenges and where legitimacy can be one such challenge.

While the above authors only touch upon the legitimation process of transformative innovation policies briefly, Karo (2018) and Diercks (2018) explicitly examine the legitimation process of TIP. In a paper on how the global–Western discourse has entered the East Asian mission-oriented innovation policy rhetoric, Karo (2018) illustrates how the new policies are legitimised through the old "developmentalist" logic. The author concludes that although transformative innovation policies are embedded in public values, such as sustainable development, they also seem to require more of a nontechnocratic mode of governance, which is not yet in place Diercks (2018). takes a closer look at OECD as a main vehicle for policy influence and how that organisation has managed to pick up the system innovation thinking and how this is affecting the policy mix it promotes. Both Karo (2018) and Diercks (2018) use discourse analysis as their main method for analysing how key ideas within the TIP framework are translated in policy organisation (although the level of analysis is on different levels of aggregation). Although identified as important, also here, they focus on challenges rather than engage in a discussion on what the transformative capacity in policy organisations actually could be built up and what it would entail.

4.4. Implementation

Implementation implies that the policy instruments are put into effect and carried out as previously planned, which involves putting an organisation in charge of implementation and providing the required human, financial and legal resources (Cairney, 2012).

Concerning the implementation stage, the reviewed literature rarely makes a clear distinction between policy formulation and policy implementation in the articles, and authors usually refer to the latter linked to the formulation stage. One reason for this might be that the literature on transformative innovation policy is still in its infancy, which means that there are many conceptual articles but not yet many transformative policies in place and, consequently, very few empirical studies of real implementation processes. In this way, many of the papers that have empirical applications involve ongoing or past experiments at the local or national levels (Bugge et al., 2017; Grillitsch et al., 2019; Peng and Bai, 2018; Seong et al., 2016). Nonetheless, several authors acknowledge that the specific character of transformative innovation policy as compared with previous generations of innovation policy implies that there is a need for new policy implementation mechanisms and processes (Foray, 2018a; Foxon and Pearson, 2008; Kuhlmann and Rip, 2018; Seong et al., 2016; Weber and Rohracher, 2012). While it remains rather unclear what those mechanisms and processes would be, some challenges are identified in the reviewed literature (see Table 5 for an overview).

In relation to the 'multi-faceted policy intervention' theme, Rogge and Reichardt (2016) highlight that in the implementation stage, policy instruments are put into action, i.e. they are executed and enforced and, as such, this stage is relevant to the instrument mix. Accordingly, in the context of sustainability transitions, the lack of implementation structures at different governance levels and

political resistance can hinder the effects of a policy instrument and hence lead to implementation difficulties (Rogge and Reichardt, 2016). Moreover, implementation is conditioned by the capabilities of the actors. This concerns the knowledge of intended adopters and users of new technologies and solutions (Bugge et al., 2017), the governance capabilities of stakeholders involved in implementation (Grillitsch et al., 2019), and the competence and implementation capacity of governments and policymakers (Berkhout and Westerhoff, 2013; Foray, 2018b; Janssen, 2019).

Regarding the "multi-level governance" theme, some authors discuss that, in the context of transformative innovation policy, the top-down governance mode of policy intervention is complemented, or even replaced, by bottom-up governance approaches (Kattel and Mazzucato, 2018; Mazzucato, 2018; Steward, 2012). In these new and "open" approaches, (part of) the responsibility for policy implementation is delegated to other stakeholders (Foxon and Pearson, 2008; Grillitsch et al., 2019; Hoppmann et al., 2014; Seong et al., 2016; Weber and Rohracher, 2012) and policymakers combine centralized "dirigisme"[6] with a more embedded and decentralized governance mode (Bugge et al., 2018; Foray, 2018b; Mazzucato, 2018). This results in an additional challenge for transformative policy in relation to the role of the state in the implementation stage, i.e. if there is a need of strong leadership to implement and guide the process towards the desired direction (Berkhout and Westerhoff, 2013; Bugge et al., 2018).

This also raises another issue, which is related to the context of the innovation processes. As illustrated by Karo (2018), while the global-Western discourse has been influencing policy design in East-Asian mission-oriented innovation policy approach, the old "developmentalist" logic (cf. Johnson, 1982) is still used in the process of legitimation and implementation of policies. This shows that, while transformative policy scholars argue towards the need of "nontechnocratic and nonrational pushes by charismatic-authority-based movements or institutions and supportive change agents" (Karo, 2018, p. 878), this would not be possible without changing the state apparatus and institutional set. Therefore, the failure to consider the constraints of the political system (political resistance), conditions and cultural context in which the policy is to be implemented remains one of the main challenges in implementing transformative innovation policy. This is supported by several authors, who argue that existing institutions can enable or hinder implementation depending on whether they are aligned with the policy being implemented (Berkhout and Westerhoff, 2013; Peng and Bai, 2018)

Linked to what was previously discussed about new governance modes and institutional settings, many challenges also emerge when involving "multiple actors" in the implementation of transformative policy. First, studies of the implementation and outcomes of transformative-oriented policy programs and initiatives show that stakeholder enrolment and motivation require policymakers to act as brokers between different stakeholders, to initiate dialogue and joint activities, build trust and align interests, and encourage collaboration (Bugge et al., 2017; Grillitsch et al., 2019; Mazzucato, 2018). However, Grillitsch et al. (2019) observe that while network power can facilitate this process, "dealing with institutional change will often go beyond the competencies of programme managers and participants" (p. 1058). Moreover, changing misaligned institutions to enable implementation (e.g. stimulate market formation) might not be within the scope or latitude of a specific program or the implementing agency (Berkhout and Westerhoff, 2013; Coenen et al., 2015b). Russell and Smorodinskaya (2018) also argue that path dependencies remaining from established hierarchical connections pose a challenge to restructuring domestic institutional contexts to better align with global transformation processes. Institutional change can also involve conflict as well as power struggles and, thus, is not always successful (Grillitsch et al., 2019; Schot and Steinmueller, 2018; Weber and Rohracher, 2012). This leads, then, to a second challenge related to this theme: the risk of conflicts of interest and power struggles.

The third challenge is related to the lack of stakeholder involvement. Grillitsch et al. (2019) point out that, usually, the variety of stakeholders participating in a program decreases substantially during the implementation stage. Accordingly, a lack of stakeholder involvement can become a barrier to implementation (Bugge et al., 2017; Peng and Bai, 2018; Seong et al., 2016), especially when it comes to the engagement of different actors to promote institutional change directed towards the transformation, i.e. institutional entrepreneurship (Grillitsch et al., 2019). Moreover, the emphasis on self-organizing and networking might come at the expense of the strong leadership and guidance required for transition processes to be realized (Berkhout and Westerhoff, 2013; Bugge et al., 2017; Grillitsch et al., 2019; Janssen, 2019; Scordato et al., 2018). This can be partially addressed by identifying the diversity of opinions, bringing together contributions from different actors, and disclosing the politics behind the innovation process (Schot and Steinmueller, 2018). However, this is more easily said than done and more research needs to be developed to identify how stakeholder involvement should be brought together and sustained during the implementation stage of innovation policies for transformative change (Grillitsch et al., 2019).

Finally, and adding to these previous challenges, weak leadership and conflicting interests can lead to difficulties in coordinating multiple actors in different levels of government. As stated by Grillitsch et al. (2019), "breadth of involvement of stakeholders groups (with potentially conflicting interests) may compromise actionability" (p. 1058). This also relates to the question of how much stakeholder involvement differs in different stages of the policy process. Moreover, Weber and Rohracher (2012) point out that a lack of vertical coordination, i.e. coordination between ministries and implementation agencies, can lead to a mismatch between strategic goals and the operational implementation of policies. Consequently, this can lead to an "implementation deficit", in which instruments are not implemented on a sufficient scale (Scordato et al., 2018).

[6] This is related to a type of system in which the government has a lot of control in the economy.

Table 6
Summary of findings related to monitoring and evaluation.

Themes	TIP-specific stage characteristics	Identified challenges
Grand challenges & Directionality	Evaluation of transition/system dynamics rather than innovation outcomes Broader set of impacts to account for, incl. unexpected or indirect impacts	Attributing the effects of policy
Multi-faced policy intervention	More complex policy mixes	Accounting for interactions between instruments
Multiple actors	Broader stakeholder involvement	Managing conflicts between stakeholders Building trust and empowering stakeholders
Multi-level governance	Evaluation as a learning tool – formative evaluation is more important	Coordinating between scientific fields, policy levels and sectors Attributing the effects of policy and performing ex-ante evaluation

4.5. Monitoring and evaluation

Monitoring and evaluation refer to the monitoring and evaluation of the result or "success" of policies (Cairney, 2012; Howlett and Giest, 2013). It includes both providing information on the observed results of the policy and assessing the value of those results (evaluation) (Dunn, 2008). The latter includes an assessment of whether the policy decision was correct, whether the implementation was appropriate and if the policy had the intended effect (Cairney, 2012).

There seems to be general agreement in the reviewed literature that the special character of transformative innovation translates into new challenges for policy evaluation – challenges that current evaluation practices are ill-suited to handle (Amanatidou et al., 2014; Grillitsch et al., 2019; Janssen, 2019; Magro and Wilson, 2018). As Magro and Wilson (2018) put it, transformative innovation policy will lead to new answers to questions such as why, what, when and how to evaluate, as well as who should be responsible for evaluating. In the following, some answers to these questions – and the challenges they imply for policymakers – will be discussed (see Table 6 for an overview).

In relation to the 'directionality' theme, the reviewed literature highlights that new rationales for policy that come with transformative innovation policy, such as transformational system failures, imply that evaluation practices have to be adapted to new aims and tasks (Amanatidou et al., 2014). Most notably, it is no longer enough to measure innovation outcomes in general but instead, the impact of policy on selected challenges, missions and transition processes have to be assessed (Janssen, 2019; Magro and Wilson, 2018; Robinson and Mazzucato, 2019).

This is also connected to the 'grand challenges and inclusive growth' theme in that some authors argue that there is a need to develop new evaluation frameworks and indicators that capture more of the complex, system-level transition dynamics, in order to allow evaluators to understand what is happening in the focal socio-technical configuration and how policy influences the conditions for realizing transformative change (Amanatidou et al., 2014; Grillitsch et al., 2019; Hoppmann et al., 2014; Janssen, 2019; Kern, 2012; Mazzucato, 2016; Mazzucato, 2018). Moreover, policy evaluation needs to consider a broader set of impacts than before (Amanatidou et al., 2014). Depending on which challenge, mission or transition is in focus, evaluation might have to consider both additional impacts within the traditional science, technology, and economy domains, for example, impacts throughout the entire innovation value chain (Robinson and Mazzucato, 2019), and impacts related to new domains, such as sustainability or other societal impacts (Amanatidou et al., 2014). This broadened scope implies a need for evaluation to consider "behavioural additionality", i.e. how policy changes the behaviour of actors involved in or affected by the policy measure in question, as well as system-level effects such as experimentation and learning (Amanatidou et al., 2014; Magro and Wilson, 2018). Due to the complexity and uncertainty of transformation processes, policy evaluation might also to a larger extent have to take unexpected or indirect impacts into account (Amanatidou et al., 2014).

Taken together, these characteristics imply that it can be a major challenge to attribute the effects of policy, since spillovers and other systemic effects confuse the input-output logic and make it difficult to define a counterfactual (Janssen, 2019). The uncertainty and long duration of transformation processes also make it more difficult to determine the influence of a particular policy (Amanatidou et al., 2014). Indeed, the final outcomes of a policy might not be fully observable for many years (Janssen, 2019).

Concerning the 'multi-faceted policy intervention' theme, transformative innovation policy tends to involve quite complex policy mixes (as described in Section 4.2). This implies a challenge for evaluators to account for synergies, conflicts and other types of interactions between instruments – something that traditional evaluation methods are not necessarily well suited for (Janssen, 2019; Magro and Wilson, 2018).

As regards the 'multiple actors and global networks' theme, the reviewed literature clearly indicates that there is a need for new forms of organisation and governance of evaluation (Magro and Wilson, 2018; Mazzucato, 2018). Just as it is argued that policy formulation and implementation should become more inclusive (see Sections 4.2 and 4.4), the reviewed literature advocates a more open and collective governance of policy evaluation to make evaluations relevant and useful. While this is not necessarily unique for transformative innovation policy evaluation (Amanatidou et al., 2014), suggestions range from addressing the needs of different stakeholders in evaluation to putting these stakeholders at centre stage of evaluation processes and empowering them to govern and evaluate themselves (Amanatidou et al., 2014; Magro and Wilson, 2018; Weber and Rohracher, 2012).

Table 7
Summary of findings related to policy learning.

TIP theme	TIP-specific stage characteristics	Identified challenges
Multiple actors	Collective sensemaking involving multiple stakeholders	Managing stakeholders (see Table 6)
Multi-level governance	Adaptive policymaking prescribed	Engaging in continuous monitoring and reflection Changing policy routines

Such broad and deep stakeholder participation involves new challenges for evaluators. Different stakeholders, within and outside of government, have different interests and as well as different stakes in policy. This means that there will be conflicts of interests of different kinds to manage – especially if the same stakeholders have been involved in designing and implementing the very same policies they are evaluating (Magro and Wilson, 2018). In addition, for stakeholder involvement to work there has to be trust, both between the evaluator and the stakeholders and between different stakeholders, in order for stakeholders to share sensitive information and commit to the evaluation process (Amanatidou et al., 2014; Magro and Wilson, 2018). This is also crucial for the legitimacy of the evaluation and its results (Magro and Wilson, 2018). However, for stakeholders to be able to commit and become engaged, they have to be empowered to do so, for example by training and facilitation of interactions (Magro and Wilson, 2018).

Finally, with reference to the 'multi-level governance' theme, the complex and fragmented nature of transformative innovation, implies an increasing need for coordination between different scientific and technological fields, policy levels and areas, and sectors (Amanatidou et al., 2014; Magro and Wilson, 2018). In addition, the reviewed literature stresses the increasing importance of evaluation for learning and reflexivity rather than accountability and control only (Janssen, 2019; Magro and Wilson, 2018). Indeed, evaluation is seen as both a governance tool and a learning tool, through which policymakers can learn important lessons for the future (Amanatidou et al., 2014). This means that policymakers and evaluators need to build "strategic intelligence" about how desired transformations are progressing and the emergent effects of policy on them (Weber and Rohracher, 2012) and that evaluations should be conducted when there is a need for information, for example when there is a window of opportunity to modify or replace a particular policy (Amanatidou et al., 2014). According to several articles, this implies that formative evaluation in the form of repeated and timely monitoring should be prioritized over summative evaluation, to allow for re-evaluation and adaptation of goals, strategies and policy instruments (Fagerberg, 2018; Janssen, 2019; Magro and Wilson, 2018; Mazzucato, 2018; Weber and Rohracher, 2012). Considering the longevity and uncertainty of transformative innovation, this is a prerequisite for a dynamic and flexible policy approach, where feedback is used to make adjustments throughout the policy process (Foray, 2018a; Foray, 2018b; Hoppmann et al., 2014; Mazzucato, 2018; Weber and Rohracher, 2012). This implies additional difficulties to attribute policy effects and can make it complicated to perform *ex-ante* evaluation, because of the high level of experimentation and risk and the limited capacity and foresight of policymakers (Foray, 2018a; Foray, 2018b; Hoppmann et al., 2014).

4.6. Policy learning

The last stage of the policy cycle is policy learning, which as described in the preceding section is intimately connected to monitoring and evaluation (Howlett and Giest, 2013). It could lead to a reformulation of problems and solutions and to specific policies being continued, modified or discontinued (Cairney, 2012; Howlett and Giest, 2013). In principle, this could be seen as the start of a new cycle, but although such a feedback loop is highly desirable it is often not realized (Howlett and Giest, 2013). The following discussion is therefore focused on the literature's perceptions of how policymakers can use the lessons they learned to improve individual policies or the policymaking process in general. This is mainly related to the 'multi-level governance' and 'multiple actors and global networks' themes as described in Section 3 (see Table 7 for an overview).

With regard to 'multi-level governance', the reviewed literature identifies three main mechanisms by which policy learning occurs: "the science of muddling through" (Lindblom, 1959 as cited by Hoppmann et al., 2014; cf. also McKelvey and Saemundsson, 2018),[7] "compulsive policymaking" (cf. also Fagerberg, 2018; Foray, 2018a; Foxon and Pearson, 2008; Hoppmann et al., 2014),[8] and "adaptive policy making" (also referred to as "tentative governance" and "reflexivity") (Amanatidou et al., 2014; Crespi, 2016; Grillitsch et al., 2019; Schot and Steinmueller, 2018; Weber and Rohracher, 2012).[9] While some scholars seem to associate TIP mainly with adaptive policymaking, we find this somewhat confusing considering that all these mechanisms are based on an understanding of innovation

[7] This refers to a rather ad hoc-type of learning-by-doing with regard to both problem formulation and selection of solutions. The underlying idea is that when complex processes are concerned, policymakers do not have the capacity to make complete problem analyses and identify optimal policy solutions before taking action. Instead, they tend to focus on a few main issues at a time and then move on as previous issues are handled or new ones appear on the agenda. They also tend to pick any policy solution that suits their direct needs – or based on fashion rather than experience – and then adjust it if and when it turns out to be inappropriate or insufficient.

[8] This refers to an iterative type of learning-by-doing, where the effects of a policy instrument in terms of technological change (e.g. rapid diffusion) forces policymakers to revise the instrument to adapt to new conditions. Policy adjustment is, thus, a reaction to real (and often unanticipated or underestimated) changes in targeted socio-technical systems. The policymakers can very well have the capacity to design and implement a policy that solves initial problems or bottlenecks, but the impact of the policy itself also results in new problems that policymakers subsequently have to address by revising the policy design.

[9] Some argue that adaptive policymaking is more reactive than reflexive policymaking (Grillitsch et al., 2019), but most articles do not make that distinction.

and transformation processes as complex and uncertain and of policy processes as characterized by large needs for trial-and-error learning. However, adaptive policymaking differs from the other mechanisms in that it is more prescriptive, i.e. it describes how policy learning should be set up rather than how it occurs. In the TIP literature, adaptive policymaking is, thus, for the most part, described as something policymakers much achieve in order to pursue successful transformative innovation policy and achieve transformative change.

It is by no means easy to achieve either policy learning in general or adaptive policy in particular. Indeed, as adaptive policymaking rests on the deliberate use of bottom-up policy experimentation and discovery, where policies and activities are continuously monitored, reviewed, adjusted and reversed based on what happens in each experiment (Amanatidou et al., 2014; Foray, 2018a; Foxon and Pearson, 2008; Magro and Wilson, 2018; Mazzucato, 2016; Schot and Steinmueller, 2018), it requires a system for continuous monitoring, reflexive and adaptive arrangements (Weber and Rohracher, 2012). However, in contexts characterized by high degrees of uncertainty, all feedback and learning are by necessity partially blind (McKelvey and Saemundsson, 2018), and there are many potential sources of "reflexivity failure" (Weber and Rohracher, 2012), such as weak leadership, lack of absorptive capacity, conflicts of interests and closed networks (Grillitsch et al., 2019; Mazzucato, 2018). Moreover, policymakers tend to follow routines, and this can make it difficult to adapt to new rationales and the associated policy practices (Grillitsch et al., 2019).

Concerning the 'multiple actors and global networks theme', some authors in the reviewed literature argue that policymaker should not be seen as someone who can take an outsider perspective, but instead as deeply embedded in a collective sensemaking and learning process, which requires reflexive and adaptive arrangements involving multiple stakeholders (e.g. public consultations) (Weber and Rohracher, 2012). Nevertheless, though learning, in general, might be a shared purpose of all stakeholders, policy learning usually is not (Magro and Wilson, 2018), which implicitly implies that it might be a challenge to get stakeholders to take responsibility for learning related to policymaking. Moreover, the stakeholder management challenges described in Section 4.5 should apply here as well.

5. TIP challenges and practical contributions

In order to simplify the next step of the analysis, i.e. to identify the literature's practical contributions, we decided to group the identified challenges into more generic "topics" that span across thematic areas and stages of the policy cycle. We call these *second order challenges* in the text that follows, and they represent the most prominent potential pitfalls identified.

Appendix B explains how the grouping was done (see also Section 2). In this section, we discuss the findings related to these second-order challenges and assess to what extent the frameworks put forward in the literature provide useful support for policymakers with regard to how to address them. In Table 8, we distinguish between frameworks that acknowledge the existence or importance of a particular challenge and frameworks that actually address the challenge in a way that can provide some guidance to policymakers.

Challenge #1 (Broadening perspectives on innovation policy) is the challenge that has been addressed most in the reviewed literature. This challenge refers to the need of reconciling different perceptions of the innovation perspective to address wicked problems, moving away from "technology-driven" and "supply-side" orientation (Diercks, 2018; Naber et al., 2017) and including societal benefits into policy design principles (Amanatidou et al., 2014; Janssen, 2019; Weber and Rohracher, 2012). Among the frameworks that address this challenge, we find several attempts to broaden the view on which problems or failures could justify policy intervention. Most notably, Weber and Rohracher (2012) build on insights from the multi-level perspective and transitions management approaches to propose a framework that combines previous conceptualizations of market and system failures with so-called transformational failures.[10] Arguing for the inclusion of a more transformative approach to innovation systems, Kivimaa and Kern (2016) instead broaden the technological innovation system framework by complementing the existing "niche creating" functions with what they call "regime destructive" functions. Chicot and Matt (2018) focus on how public procurement of innovation (PPI) can contribute to grand challenges and identify three types of failures that PPI, specifically, could help to resolve: demand-side failures, supply-side failures, and user-supplier interaction failures.

Additionally, Foray (2018a) proposes a framework that builds upon an "eclectic" approach to building innovation policy rationales. As such, he points out the need to broaden the "moderate" innovation policy approach, which includes neutral (or generic) interventions to fix market failures, towards a more "radical" approach, which, in turn, involves non-neutral (or preferential) interventions to fix coordination and directionality failures. From a missions-oriented policy perspective, Mazzucato (2016), Mazzucato (2018) and Kattel and Mazzucato (2018) reiterate the need to complement the market fixing view on policy with a marketing-creating approach and discuss a practical approach to implement such policies. In this way, they endorse the interplay between horizontal and vertical policies, and the need for "tilting" the playing field in a direction more normatively guided than previous innovation processes. Diercks et al. (2019) argue that transformative innovation policy implies a societal agenda that tackles various societal domains and includes a broader understanding of the innovation process. As such, their framework can help policymakers compare and contrast policy initiatives in terms of how transformative they are, i.e. on whether they include an economic or social perspective and a narrow or broader view of the innovation process.

A few contributions could be linked to challenge #4 (Characterizing and attributing policy effects). This challenge is related to the lack of evaluation practices for assessing policy-mixes and transformative policy as well as designing formative evaluations (Amanatidou et al., 2014). While many authors acknowledge the need for new evaluation practices to attributing policy effects, only a few

[10] These are: directionality, demand articulation, policy coordination, and reflexivity failures.

Table 8
Second-order challenges and practical contributions.

Frameworks[a,b]		#1 Broadening perspectives on innovation policy	#2 Translating societal goals into concrete policy targets and practices	#3 Coordinating across policy domains and levels	#4 Characterising and attributing policy effects	#5 Empowering a broader set of stakeholders	#6 Balancing influence from incumbent actors	#7 Managing power struggles and conflicts of interests	#8 Navigating past policy dependencies	#9 Developing institutional & governance capacity
Bugge et al. (2017) and Bugge et al. (2018)	Framework based on SNM and transformational failures to explore different modes of governance	Addressed	-	Acknowledged, but not addressed	Addressed	Acknowledged, but not addressed	-	-	-	Acknowledged, but not addressed
Chicot & Matt (2018)	Framework on "public procurement of innovation" for addressing grand challenges	Addressed	Addressed	-	-	-	-	-	-	-
Diercks et al. (2019)	Framework for assessing innovation policy paradigms	Addressed	-	-	-	-	-	-	-	-
Foray (2018a)	Framework on non-neutral innovation policy and modes of policy interventions	Addressed	Acknowledged, but not addressed	Acknowledged, but not addressed	-	-	-	-	-	-
Grillitsch et al. (2019)	Framework based on transformational failures and TIS for translating the challenges of system innovation policy for policy action and analysis	Acknowledged, but not addressed	Addressed	Acknowledged, but not addressed	-	-	-	-	-	Acknowledged, but not addressed
Janssen (2019)	Framework for assessing the impact of transformative policy	Acknowledged, but not addressed	-	Acknowledged, but not addressed	Addressed	-	Acknowledged, but not addressed	Addressed	-	Acknowledged, but not addressed
Johnstone et al. (2017)	Framework that analyses policy mixes for incumbency	-	-	-	-	-	Addressed	Acknowledged, but not addressed	-	-
Kern (2012)	The frameworks uses the MLP as a heuristic to ex-	-	-	-	Addressed	-	Acknowledged, but not addressed	-	-	Acknowledged, but not addressed

(*continued on next page*)

Table 8 (*continued*)

Frameworks[a,b]		#1 Broadening perspectives on innovation policy	#2 Translating societal goals into concrete policy targets and practices	#3 Coordinating across policy domains and levels	#4 Characterising and attributing policy effects	#5 Empowering a broader set of stakeholders	#6 Balancing influence from incumbent actors	#7 Managing power struggles and conflicts of interests	#8 Navigating past policy dependencies	#9 Developing institutional & governance capacity
	ante assess policies									
Kivimaa & Kern (2016)	Framework that broadens the TIS functions by adding the so-called the dimensions of "creative destruction"	Addressed	-	Acknowledged, but not addressed	Addressed	-	Addressed	Acknowledged, but not addressed	Acknowledged, but not addressed	Acknowledged, but not addressed
Kivimaa & Virkamäki (2014)	Framework for assessing policy mixes from a systemic perspective	Acknowledged, but not addressed	Acknowledged, but not addressed	-	-	-	Acknowledged, but not addressed	Acknowledged, but not addressed	-	-
Naber et al. (2017)	Analytical typology based on SNM for upscaling sustainable energy innovations	Acknowledged, but not addressed	-	-	Acknowledged, but not addressed	Acknowledged, but not addressed	Acknowledged, but not addressed	Acknowledged, but not addressed	-	-
Mazzucato (2016, 2018) Kattel & Mazzucato 2018	Framework for the selection of missions	Addressed	Addressed	Acknowledged, but not addressed	Acknowledged, but not addressed	Acknowledged, but not addressed	-	-	Acknowledged, but not addressed	Acknowledged, but not addressed
Rogge and Reichardt (2016)	Framework for analysing policy mixes	-	-	Addressed	Acknowledged, but not addressed	-	-	-	Addressed	-
Weber & Rohracher (2012)	Comprehensive transformational system failures	Addressed	Acknowledged, but not addressed	Acknowledged, but not addressed	Acknowledged, but not addressed	-	-	-	Acknowledged, but not addressed	Acknowledged, but not addressed

[a] We included only papers of frameworks which suggest some type of practical contribution in relation to the identified second-order challenges (authors' own assessment). The analysis included three main categories: (i) addressed, meaning that the framework addresses the specific challenge and provide guidance for policymakers on its practical usefulness; (ii) acknowledge, but not addressed, which refers to those papers that touch upon the specific challenge but do not provide any concrete and practical guidance on how to address it; and (iii) not addressed (-), when the framework does not mention or address the challenge. It should be noted that we only assessed the frameworks in relation to the identified second-order challenges. This implies that the frameworks could still be practically useful in some other sense.

[b] Frameworks are listed in alphabetical order.

put forward frameworks that can be used in practice. It should be noted that they do not focus on evaluating the outcome of policy in relation to the end goal (e.g. reduced climate emissions), but rather target more intermediate outcomes such as key processes of transformative change or the characteristics of the policy mix. Departing from the multi-level and strategic niche management perspectives, Kern (2012) develops a framework to assess policies ex-ante in order to shed light on how policies contribute to socio-technical transitions. His framework can be used to assess to what degree specific policy initiatives influence niche- and regime-level processes and how they, in turn, are helped or hindered by landscape pressures. Janssen (2019) instead builds on Technological Innovation Systems (TIS) and the "functional" approach to assess the aggregated impact of transformative innovation policy. He highlights the need to first identify the main functional bottlenecks and blocking mechanisms before assessing how effectively the policy mix directly and indirectly has strengthened the most important functions for advancing the TIS. Combining the transformational failures dimensions introduced by Weber and Rohracher (2012) with insights from strategic niche management, Bugge et al. (2017) compare how two different government programs address the four transformational failures, and in which way the programmes have 'shielded', 'nurtured' and 'empowered' emerging technologies (cf. Smith and Raven, 2012). Bugge et al. (2018) use the same framework to describe (and assess) different governance roles (related to transformational failures) and modes of governance (top-down versus bottom-up) in relation to a government-led initiative to promote new technologies in the healthcare sector.

Some contributions can be also linked to challenge #2 (Translating societal goals into concrete policy targets and practices). This second-order challenge refers to the need to translate grand challenges into actionable problems and practice, including the types of inequalities and behaviour to target (Diercks, 2018; Grillitsch et al., 2019; Mazzucato, 2016). Mazzucato (2018) and Kattel and Mazzucato (2018) provide guidance on how missions should be formulated to tackle grand challenges and, more specifically, list a set of criteria for picking missions. Additionally, Chicot and Matt's (2018) framework, which links different types of public procurement of innovation (PPI) initiatives to different types of system failures, could help policymakers assess the suitability of different PPI initiatives in addressing grand challenges. Also based on a failures approach, but drawing on Weber and Rohracher's (2012) transformative failures framework, Grillitsch et al. (2019) explicitly account for this challenge in a discursive analytical framework, in which they suggest to "set objectives that provide direction in a clear and actionable way" (p. 1050). This means aligning the interests of broader stakeholder groups to agree with these objectives, which is a result of long processes of negotiation.

Challenge #6 (Balancing influence from incumbent actors) is addressed by fewer contributions. Kivimaa and Kern (2016) argue that sustainability transitions are formed by both "motors of innovation" and "motors of creative destruction". As such, the authors (as mentioned above) add "destruction functions" to the technological innovation systems functions framework. These include policy mixes aiming at mitigating the influence of incumbent actors to allow the niche to break through the regime. Also building on the concept of "creative destruction", Johnstone et al. (2017) analyse how incumbency is reproduced and forged through the process of "destructive re-creation". In this way, the authors disclose some of the strategies incumbents use to reproduce the patterns around specific technologies. This can serve as an eye-opener for policymakers when designing interventions for sustainability transitions, as it shows the need to address "profoundly grounded cultural pivots and institutional levers" to tackle deep incumbency (Johnstone et al., 2017, p. 157).

Three of the second-order challenges were acknowledged at length, but only addressed in one article each. Rogge and Reichardt (2016) address challenge #3 (Coordinating across policy domains and levels) by developing a framework which allows for the analysis of policy mixes based on its building blocks (i.e. policy elements, processes and characteristics) and dimensions (e.g. policy field, governance level, geography and time). This framework can provide guidance on how to improve "both the consistency of the elements of the policy mix and the coherence of policy processes", and hence the coordination of policy (Rogge and Reichardt, 2016, p. 1632). This same framework also brings insights for addressing Challenge #8 (Navigating past path dependencies), which includes challenges such as the failure to consider the constraints of the political system and cultural context, the interrelatedness of policies (ex. policy drift, layering, conversion), and limiting policymaker manoeuvring (Kivimaa and Kern, 2016; Schot and Steinmueller, 2018). These aspects are accounted for in the dimensions part of the framework, which accounts for the "space in which interactions can occur" and guide the specification of the building blocks of the policy mix (Rogge and Reichardt, 2016, p. 1627). Challenge #7 (Managing power struggles) is addressed to a certain extent by Janssen's (2019) framework, which in addition to evaluation includes design principles for policy orientation, such as establishing direction and contestation processes, which can mitigate conflicts.

Finally, some second-order challenges are acknowledged but remain largely unaddressed in the literature. For instance, many authors acknowledge challenge #9 (Developing Institutional and Governance Capacity), but do not provide practical guidance on how to address it, although some general insights can still be derived. For instance, Weber and Rohracher (2012) discuss the implications of reflexivity failures to the governance of transformative policy, which would encompass continuous monitoring and anticipation, reflexive arrangements of societal discourses, as well as the admission of a portfolio of approaches to deal with uncertainty. Moreover, Bugge et al. (2018) introduce the notion of "governance mix" referring to the need to expand the policy-mix concept to include the notion of meta-governance and modes of governance. However, they provide no guidance on how to do it. For challenge #5 (Empowering a broader set of stakeholders), numerous specific challenges are acknowledged, ranging from the need for trust-building (Coenen et al., 2015), empowerment issues (Magro and Wilson, 2018), stakeholder apathy (Bugge et al., 2017), difficulty in promoting institutional entrepreneurship and coordination of directionality across actor networks (Grillitsch et al., 2019). However, no specific means of addressing them were identified in the review.

In summary, we find that much of the same challenges are identified throughout the literature, although authors differ in the depth and means by which they discuss them. Some contribute with analytical or theoretical frameworks, others share reflections from their empirical observations, and yet others bring new ideas to the table which remain to be tested. As a whole, however, most of the identified challenges remain largely unaddressed.

Concluding discussion

In this paper, we have reviewed the emerging literature on "third-generation" or "transformative" innovation policy, focusing on how it contributes to our understanding of the policymaking process. The purpose of the paper was to take stock of the current understanding of the specificities of transformative innovation policy and the challenges it involves throughout the policy cycle and to examine the actual contributions of the received literature to practical policymaking.

The review showed that there is a growing body of literature on TIP in both the literature on socio-technical transitions (e.g., Diercks et al., 2019.; Schot and Steinmueller, 2018; Weber and Rohracher, 2012) and the literature on mission-oriented innovation policy (e.g., Foray, 2018b.; Mazzucato, 2016). Although these literatures have somewhat different starting points, they have over time developed a very similar understanding of the key differences between TIP and previous innovation policy generations. We identified five main distinguishing characteristics of TIP as broadly agreed upon in the received literature: (1) focus on grand challenges and inclusive growth, (2) directionality as a key feature, (3) multi-faceted policy interventions, (4) involvement of a broader set of actors and global networks, and (5) multi-level governance. We also found that the two literature strands differ somewhat in how they approach these characteristics at a more detailed level. Most notably, missions-oriented policy has a more top-down approach to problem directionality (i.e. defining the mission) than transitions-oriented innovation policy However, in spite of these differences the rest of the review showed that the two strands for the most part have a common understanding of the challenges TIP implies for the policymaking process.

We then analysed the literature's understanding of how the main distinguishing characteristics of TIP could influence the policymaking process. We departed from the policy cycle model (Cairney, 2012; Howlett and Giest, 2013) and identified specific challenges associated with TIP for each stage of the cycle. Through the analysis, it becomes clear that the emerging literature, in spite of its early phase of development, deals with all parts of the cycle and brings up relevant challenges for policymakers to address. However, it does not give equal attention to all stages; while 'agenda-setting' has been thoroughly discussed, mainly as a consequence of the increased focus on directionality, the TIP literature has so far paid little attention to the 'legitimation' process of various transformative policies. Moreover, it does not distinguish clearly between policy formulation and policy implementation, as authors for the most part include implementation in the formulation stage and do not recognize that they are two distinct processes with their own logic and characteristics.

We have also identified three gaps that cut across the different stages of the policy cycle. These are topics that so far have not been much discussed in the reviewed literature and that we believe would have to be addressed in order to make real contributions for practical policymaking. First, considering that a large number of articles emphasise the importance of multi-level stakeholder interaction and coordination for addressing directionality and other types of transformative challenges, it is somewhat surprising that there is so little analysis of the actual role and contribution of different stakeholders in relation to the transformative challenges. Here, the TIP literature could make use of various role-based typologies (Mossberg et al., 2018; Perez Vico et al., 2015) as well as empirical studies of specific types of actors, such as different types of intermediaries (cf., e.g., Kivimaa et al., 2019; Moss, 2009), in relation to policymaking and governance. Moreover, we would like to see a more detailed discussion about how stakeholder involvement can be achieved and organized to bring out the intended outcomes. In particular, challenges related to handling previously identified risks of democratic deficits and policy capture at different governance levels – ranging from national innovation councils (Fagerberg and Hutschenreiter, 2020) to specific transition arenas or networks (Voß et al., 2009) – should be highlighted more. Here, the emerging TIP literature can draw significant insights from the literature on stakeholder management, which both has a more nuanced perspective on the relative benefits and drawbacks of stakeholder involvement in different contexts and a more developed understanding of the challenges involved in organizing and managing multi-stakeholder processes (and how these could be addressed) than what we so far have seen in the TIP literature (cf., e.g., Edelenbos and Klijn, 2005; Hemmati, 2002; Riege and Lindsay, 2006; Waligo et al., 2014; Warner, 2006).

A second gap relates to the call for "organizational flexibility and responsiveness to new information" by Kattel and Mazzucato (2018, p. 791). While this need for public sector actors to develop "dynamic capabilities" (Teece et al., 1997) is repeated in different wordings throughout the reviewed TIP literature, it does not really engage in any discussion about what such capabilities entail and how they could be built up. Moreover, the notion of flexible and "playful" policy experimentation (Kattel and Mazzucato, 2018), aiming to develop the policymakers' own political, analytical, and operational capacity, contrasts with recurrent calls for reliable and consistent policy mixes throughout the sustainability transitions literature (cf., e.g., Foxon and Pearson, 2008; Kern and Howlett, 2009; Kivimaa and Mickwitz, 2011; Reichardt and Rogge, 2016; Rogge and Reichardt, 2016). Even though policy experimentation can potentially be conducted at a small scale and, at least to some extent, outside the established policy mix (Kivimaa and Rogge, 2020), all officially approved and implemented policies – even experimental ones – require some degree of institutional change, with the associated uncertainty for affected stakeholders. While this is problematized in some articles, we found no detailed discussions on how policy experiments should be designed to be able to ensure both stability and flexibility.

The third gap concerns the impact of policy on system dynamics. Within the TIP literature, the discussion on policy mixes has mainly been concerned with evaluating policy mixes as such (e.g. their consistency and coherence) rather than their impact on innovation system and transition dynamics. While some attempts have been made in the reviewed literature to link policy mix elements to innovation system functions (with the addition of new transformative features) (Janssen, 2019; Kivimaa and Virkamäki, 2014) or transitional failures (Bugge et al., 2017; Bugge et al., 2018; Grillitsch et al., 2019), more work is clearly needed to help policymakers design and implement relevant formative and summative assessments of transformative innovation policy instruments and programmes.

Finally, we examined the practical policy contribution of fourteen frameworks in relation to nine overarching policy challenges,

which were derived through a synthesis of the challenges found in the analysis of the policy cycle. Somewhat surprising, these frameworks for the most part do not provide much guidance to policymakers with regard to how they should address the challenges associated with TIP, although the literature has been instrumental in identifying these challenges. The main exception relates to the challenge that we label 'broadening the perspectives on innovation policy', where concrete suggestions on how to think about and conceptualize the third generation of innovation policy are provided. However, in our experience understanding how TIP might differ from previous innovation policy frames is not the same as being able to design, implement and evaluate transformative innovation policy instruments and programs. If the proponents of the TIP concept want it to progress into becoming a valuable tool for practical policymaking, more concrete models and frameworks, building on insights of the everyday realities of policymakers, need to be created also for the other aspects of the policymaking process – not least 'developing institutional and governance capacity'.

To sum up, the emerging literature on transformative innovation policy has so far done a good job when it comes to defining and describing the distinguishing characteristics of this new policy paradigm and describing some implied challenges for policymakers. Considering the early stage of development of this literature, it is not surprising that most of the literature so far has been focused on justifying the need for a new approach to innovation policy to address 'grand' societal challenges and on establishing the theoretical foundations of this emerging approach. However, more practical advice about how it could be implemented is now needed for TIP to get off the academic drawing board and have an impact on real-life policymaking. In the latest writings, which were published after this review was conducted, we have seen some promising developments along these lines. We now urge TIP scholars to increase their efforts even further to explicitly and directly consider the practitioners' perspective and to develop more concrete models, tools and guidelines to help policy practitioners address challenges within and across all stages of the policy cycle.

CRediT authorship contribution statement

Carolina R. Haddad: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Valentina Nakić:** Conceptualization, Methodology, Formal analysis, Writing – original draft. **Anna Bergek:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Supervision, Funding acquisition. **Hans Hellsmark:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. All of the sources of funding for the work described in this publication are acknowledged below.

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Appendix A

Table A

Table A
List of papers included in the review (chronological order (alphabetical order within each year)).

Author	Year	Title	Journal	Mention of policy cycle stage	
				Main	Secondary
Foxon	2008	Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime	Journal of Cleaner Production	-	Agenda-setting, policy formulation, implementation, monitoring and evaluation and policy learning
Taylor	2008	Beyond technology-push and demand-pull: Lessons from California's solar policy	Energy Economics	Policy formulation	Implementation and monitoring and evaluation

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Table A (*continued*)

Author	Year	Title	Journal	Mention of policy cycle stage	
				Main	Secondary
Raven and Verbong	2009	Boundary crossing innovations: Case studies from the energy domain	Technology in Society	-	Policy formulation
Alkemade et al.	2011	Transition policy and innovation policy: Friends or foes?	Environmental Innovation and Societal Transitions	-	Agenda-setting
Cagnin et al.	2012	Orienting European innovation systems towards grand challenges and the roles that FTA can play	Science and Public Policy	Agenda-setting	Policy formulation and implementation
Edquist and Zabala-Iturriagagoitia	2012	Public Procurement for Innovation as mission-oriented innovation policy	Research Policy	-	Policy formulation and implementation
Kern	2012	Using the multi-level perspective on socio-technical transitions to assess innovation policy	Technological Forecasting and Social Change	-	Monitoring and evaluation
Steward	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 and Strategic Management	Agenda-setting and policy formulation	Implementation
Weber and Rohracher	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	Agenda-setting, implementation and monitoring and evaluation	Policy formulation and legitimation
Berkhout and Westerhoff	2013	Local energy systems: Evaluating network effectiveness for transformation in British Columbia, Canada	Environment and Planning C: Government and Policy	-	Implementation
Amanatidou et al.	2014	Using Evaluation Research as a Means for Policy Analysis in a	Minerva	Monitoring and evaluation	Agenda-setting, policy formulation and policy learning

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Table A (*continued*)

Author	Year	Title	Journal	Mention of policy cycle stage	
				Main	Secondary
		'New' Mission-Oriented Policy Context			
Hoppmann et al.	2014	Compulsive policy-making - The evolution of the German feed-in tariff system for solar photovoltaic power	Research Policy	-	All, except for agenda setting
Kivimaa and Virkamäki	2014	Policy mixes, policy interplay and low carbon transitions: The case of passenger transport in Finland	Environmental Policy and Governance	-	Policy formulation, monitoring and evaluation and policy learning
Coenen et al.	2015	Innovation Policy for Grand Challenges. An Economic Geography Perspective	Geography Compass	-	Agenda-setting
Coenen et al.	2015	Path Renewal in Old Industrial Regions: Possibilities and Limitations for Regional Innovation Policy	Regional Studies	Implementation	Agenda-setting and policy formulation
Crespi	2016	Policy complexity and the green transformation of the economies as an emergent system property	Environmental Economics and Policy Studies	-	Agenda-setting, policy formulation, implementation and policy learning
Kivimaa and Kern	2016	Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions	Research Policy	-	Agenda-setting, policy formulation and legitimation
Mazzucato	2016	From market fixing to market-creating: a new framework for innovation policy	Industry and Innovation	-	Agenda-setting and monitoring and evaluation
*Rogge and Reichardt	2016	Policy mixes for sustainability transitions: An extended concept and framework for analysis	Research Policy	Policy formulation and implementation	Agenda-setting, legitimation, monitoring and evaluation, and policy learning
Seong et al.	2016	Korea's transition experiments as a post catch-up project	Asian Journal of Technology Innovation	Implementation	Agenda-setting, legitimation and monitoring and evaluation
Bugge et al.	2017	Governing system innovation: assisted living experiments in the UK and Norway	European Planning Studies	-	Agenda-setting and implementation
Johnstone et al.	2017	Policy mixes for incumbency: Exploring the	Energy Research and Social Science	-	All, except policy learning

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Table A (*continued*)

Author	Year	Title	Journal	Mention of policy cycle stage Main	Secondary
		destructive recreation of renewable energy, shale gas 'fracking,' and nuclear power in the United Kingdom			
Naber et al.	2017	Scaling up sustainable energy innovations	Energy Policy	-	Agenda setting and monitoring and evaluation
Bugge et al.	2018	Governing socio-technical change: Orchestrating demand for assisted living in ageing societies	Science and Public Policy	-	Implementation
Chicot and Matt	2018	Public procurement of innovation: A review of rationales, designs, and contributions to grand challenges	Science and Public Policy	Agenda-setting	Policy formulation
Diercks	2018	Lost in translation: How legacy limits the OECD in promoting new policy mixes for sustainability transitions	Research Policy	-	All, except policy learning
Fagerberg	2018	Mobilizing innovation for sustainability transitions: A comment on transformative innovation policy	Research Policy	-	Policy formulation, monitoring and evaluation and policy learning
Foray	2018	Smart specialization strategies as a case of mission-oriented policy-a case study on the emergence of new policy practices	Industrial and Corporate Change	-	Agenda-setting, policy formulation, implementation and monitoring and evaluation
Foray	2018	On sector-non-neutral innovation policy: towards new design principles	Journal of Evolutionary Economics	Policy formulation	Implementation and monitoring and evaluation and policy learning
Giuliani	2018	Regulating global capitalism amid rampant corporate wrongdoing -Reply to "Three frames for innovation policy"	Research Policy	-	Agenda-setting
Karo	2018	Mission-oriented innovation policies and bureaucracies in East Asia	Industrial and Corporate Change	-	Legitimation and implementation

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Table A (*continued*)

Author	Year	Title	Journal	Mention of policy cycle stage	
				Main	Secondary
Kattel and Mazzucato	2018	Mission-oriented innovation policy and dynamic capabilities in the public sector	Industrial and Corporate Change	-	Agenda-setting, policy formulation and implementation
Kuhlmann and Rip	2018	Next-generation innovation policy and Grand Challenges	Science and Public Policy	-	Agenda-setting, policy formulation, legitimation and implementation
Magro and Wilson	2018	Policy-mix evaluation: Governance challenges from new place-based innovation policies	Research Policy	Monitoring and evaluation	Policy learning
Mazzucato	2018	Mission-oriented innovation policies: Challenges and opportunities	Industrial and Corporate Change	-	All
McKelvey and Saemundsson	2018	An evolutionary model of innovation policy: Conceptualizing the growth of knowledge in innovation policy as an evolution of policy alternatives	Industrial and Corporate Change	Policy learning	Policy formulation and monitoring and evaluation
Peng and Bai	2018	Experimenting towards a low-carbon city: Policy evolution and nested structure of innovation	Journal of Cleaner Production	Implementation	Policy formulation and monitoring and evaluation
Raven and Walrave	2018	Overcoming transformational failures through policy mixes in the dynamics of technological innovation systems	Technological Forecasting and Social Change	-	Agenda-setting and policy formulation
Russell and Smorodinskaya	2018	Leveraging complexity for ecosystemic innovation	Technological Forecasting and Social Change	-	Implementation
Schot and Steinmueller	2018	Three frames for innovation policy: R&D, systems of innovation and transformative change	Research Policy	Agenda-setting	Policy formulation, legitimation, implementation, monitoring and evaluation and policy learning
Scordato et al.	2018	Policy mixes for the sustainability transition of the pulp and paper industry in Sweden	Journal of Cleaner Production	Agenda-setting and legitimation	Policy formulation and implementation
Diercks et al.	2019	Transformative innovation policy: Addressing variety in an emerging policy paradigm	Research Policy	Agenda-setting	Policy formulation and implementation

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Table A (*continued*)

Author	Year	Title	Journal	Mention of policy cycle stage	
				Main	Secondary
Grillitsch et al.	2019	Innovation policy for system-wide transformation: The case of strategic innovation programmes (SIPs) in Sweden	Research Policy	-	Agenda-setting, implementation, monitoring and evaluation and policy learning
Janssen	2019	What bangs for your buck? Assessing the design and impact of Dutch transformative policy	Technological Forecasting and Social Change	Policy formulation and monitoring and evaluation	Agenda-setting, legitimation and implementation
Robinson and Mazzucato	2019	The evolution of mission-oriented policies: Exploring changing market creating policies in the US and European space sector	Research Policy	Agenda-setting and monitoring and evaluation	Policy formulation
Soete	2019	Science, technology and innovation studies at a crossroad: SPRU as case study	Research Policy	-	Agenda-setting and implementation

* Papers added via snowballing.

Appendix B

Table B

Table B
First- and second-order challenges.

Second-order challenges	First-order challenges	Policy cycle stage
Broadening perspectives on innovation policy	Reconciling perceptions on the narrowness/breadth of innovation perspective	Agenda-setting
	Targeting multiple objectives	Policy formulation
	Stimulating both technical and non-technical solutions	Policy formulation
Translating societal goals into concrete policy targets and practices	Translating Grand challenges into concrete actionable problems	Agenda-setting
	Stimulating experimentation and demand with a multitude of instruments	Policy formulation
	Differentiating support based on technology maturity	Policy formulation
	Finding the right "granularity" of policy	Policy formulation
	Translating transformative ideas into policy practice in dominating policy organisations	Legitimation
Coordinating across policy domains and levels	Coordinating across different domains and on various level (regional, national, global)	Agenda-setting
	Combining 'horizontal' and 'vertical' policies	Policy formulation
	Identifying and aligning the "right" combination of instruments	Policy formulation
	Coordinating policy through mutual adaptation	Policy formulation
	Handling fragmentation across policy areas and governance levels	Policy formulation
	Coordinating policy between different levels of government	Implementation
	Coordinating between scientific fields, policy levels and sectors	Monitoring and Evaluation
Characterising and attributing policy effects	Accounting for interactions between instruments	Monitoring and Evaluation
	Attributing the effects of policy and performing ex-ante evaluation	Monitoring and Evaluation
Empowering a broad set of stakeholders	Coordinating directionality between multiple-actors and global networks	Agenda-setting
		Agenda-setting

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Table B (*continued*)

Second-order challenges	First-order challenges	Policy cycle stage
	Promoting institutional entrepreneurship directed towards socio-technical change	
	Recognizing key actors, such as regions	Policy formulation
	Activating stakeholders with a clear transition agenda	Legitimation
	Involving stakeholders	Implementation
	Building trust, aligning interests, and encouraging collaboration between different stakeholders	Implementation
	Building trust and empowering stakeholders	Monitoring and Evaluation
	Managing stakeholders (see Table 6)	Policy learning
Balancing influence from incumbent actors	Undue influence from incumbent actors	Agenda-setting
	Destabilising existing locked-in socio-technical systems	Policy formulation
	Avoiding "destructive recreation"	Legitimation
Managing power struggles and conflicts of interests	Handling conflicts of interest and power struggles	Implementation
	Managing conflicts between stakeholders	Monitoring and Evaluation
Navigating past policy dependencies	Understanding constraints of the political system and cultural context	Implementation
	Changing policy routines	Policy learning
Developing Institutional and Governance Capacity	Lack of shared vision and insufficient regulation to guide change	Agenda-setting
	Ensuring autonomy of state throughout the formulation process	Policy formulation
	Strengthening domain knowledge and analytical capacity	Policy formulation
	Handling changing legitimacy over the course of implementation and time	Legitimation
	Developing appropriate governance structures	Legitimation
	Creating learning platforms	Legitimation
	Building sufficient implementation structure and capacity	Implementation
	Balancing trade-offs between strong leadership and guidance required for the transition process	Implementation
	Engaging in continuous monitoring and reflection	Policy learning

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