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Abstract

Mission-oriented policies (MOP) aim to address societal challenges by catalyzing innovation and sectoral policies towards defined goals. However, literature remains vague on the structures within societal challenges and how they can be broken down into manageable issues. We argue that especially the hierarchical dimension of problems and solutions remains understudied, creating difficulties to analyze the directionality of missions. Based on the concept of the problem-solution space, we propose a novel analytical framework, the "mission firmament", as an attempt to map the complex relationships between problems and solutions in the context of societal challenges. It contains hierarchies of debated issues, shows how societal views con- or diverge on certain aspects, considers temporality of debates and emphasizes potential leverage points for missions to maximize their contributions to solving societal challenges. We illustrate our framework with the case of the national strategy for circular economy in Germany.

Keywords: mission-oriented policies, problem-solution space, directionality, wicked problems, societal challenges

1. Introduction

Mission-oriented policies (MOP) are increasingly recognized for their potential to address societal challenges, such as climate change, public health, and social inequality (Janssen et al 2021; Boon & Edler 2018; Wittmann et al. 2021; Nylén et al. 2023; Mazzucato 2018). The efficacy of these policies heavily relies on the concept of directionality i.e. ensuring that the trajectory of innovation aligns with the desired societal outcomes (Weber & Rohracher 2012).

In this context, MOP scholars have emphasized the need to "break down" societal challenges into manageable issues (Robinson & Mazzucato 2019). Such issues might pertain to problems and solutions within societal challenges that societal views converge. This in turn can guide the setting of direction in MOP (Wanzenböck et al. 2020). Despite the pivotal role of this argument in current debates and its application (e.g. Brett et al. 2023; Borrás & Schwaag Serger 2022; Rohracher & Ornetzeder 2024) little is known about how problems and solutions are structured and relate to each other. This gap creates difficulties for the systematic analysis of MOP and their directionality. More particularly, current analyses and comparisons of missions struggle to explain why missions tackling similar societal challenges in different institutional settings and countries opt for different access points i.e. choosing different options for mission targets and issues to address in mission design and the problem-solving process.

In this paper, we explore the relationships between problems and solutions in MOP. Our argument centers on hierarchies that emerge in debates on problems and solutions within societal challenges. From this perspective, discourse on societal challenges consists of layers of problems and solutions that can relate to each other through a nesting logic. As MOP are increasingly applied in "wicked" contexts (Head 2008), these problem-solution structures might only partially become recognizable. This is due to selective societal alignment i.e. relevant stakeholders agreeing on certain issues while disregarding or refusing others and the dynamics by that debates change over time.

The proposed framework in this paper offers a perspective for disentangling the often complex and nested structures of problems and solutions within societal challenges. Thereby we add in multiple ways to the literature. First of all, we contribute to a clarification of the relation of societal challenges with more specific problems and solutions that has been discussed particularly in the context of the problem-solution space (Wanzenböck et al. 2020). Secondly, the framework ties in with recent debates about setting direction in transformative policy-making (Bergek et a. 2023) emphasizing the different possible systemic configurations to be taken into account. Thirdly, the framework links structures within societal challenges to more concrete policy-making by showing distinct leverage points in the selection of problems and solutions to target in MOP.

In this paper, we first elaborate on existing theoretical contributions on problems and solutions in MOP literature. This is followed by the conceptualization of a "mission firmament" i.e. a framework that considers a. relevant structures of problems and solutions within societal challenges from a hierarchy perspective b. conditions of wickedness and temporality with regard to these structures c. potential leverage points for MOP to pinpoint promising constellations of issues. Finally, we use the example of the recently published

national circular economy strategy in Germany to illustrate the applicability of our framework.

2. Problems and solutions in mission-oriented policies

Societal challenges require socio-technical transitions i.e. wide scale systemic change in order to improve lives. In case actors fail to coordinate for collectively innovating towards better societal outcomes, they might lack a shared vision, goal or understanding of acceptable pathways for transformation (Weber & Rohracher 2012). Accordingly, setting direction means prioritizing certain systemic innovation processes over others (Schot & Steinmüller 2018; Foray 2019) and thus represents normative decision-making (Köhler et al. 2019).

MOP have been suggested as an approach to address societal challenges. They can be referred to as public policies that seek to direct innovation towards societal goals (Robinson & Mazzucato 2019). These goals are embodied in missions that represent the explicit formulation of desirable future states or achievements often explicated with concrete timeframes and quantification (Mazzucato 2018).

But setting direction in MOP is more than defining one goal. Decisions affecting direction might relate to what we can call *mission objects* as relevant topics within societal challenges to focus on in missions. Defining such objects might roughly take place in two relevant phases of MOP: First, the choice of overarching issues at the start of initiatives (Mazzucato 2018). This relates to a. overarching missions or mission areas (e.g. in the Dutch "Mission-driven Top Sectors and Innovation Policy" several missions address the issue of the energy transition) (Larrue 2021) b. the definition of mission statements as desirable future states or achievements c. mission projects that are formed within missions. Second, the problem-solving process in that issues are tested and diffused into markets (Mazzucato 2018). As such, it is crucial in MOP to identify the interplay of issues at different levels of societal challenges like more overarching issues as goals for broader initiatives or more specific lower-level issues handled in the problem-solving process.

The identification of mission objects entails choosing not only issues to be addressed but manageable ones - i.e. issues that can actually be solved (Robinson & Mazzucato 2019). Mazzucato (2021) promotes the "breaking down" of Sustainable Development Goals (SDGs) by translating them into desirable future states or achievements. However, even though referring to overarching problems that are broken down into more manageable problems, the term "problem" seems to encompass conceptually undifferentiated issues i.e. all instances that require political intervention.

Recently, various studies have picked up on a more detailed differentiation of problems and solutions as part of MOP (e.g. Wittmann et al. 2021; Reike et al. 2021; Borrás and Schwaag Serger 2022; Uyarra et al. 2023). This differentiation of problems and solutions is based on an influential framework by Wanzenböck et al. (2020). Though not explicitly promoting a "breaking down" of challenges, they provide a framework, the so-called "problem-solution space", to understand issues within societal challenges in order to design effective MOP. Scholars from different literature streams have applied the framework in a more or less detailed manner e.g. as empirical application (Bugge et al. 2021), as part of conceptual frameworks (Elzinga et al. 2023), for operationalizing the problem-solution space (Wiarda et al. 2023) or to merely refer to it in explaining changes of societal problems and solutions (Coenen et al. 2023) (detailed overview in online appendix).

Showing how the core problem(s) and solution(s) can vary in their degree of wickedness, Wanzenböck et al. (2020) argue for a process-oriented perspective and considering particular

contexts. It is proposed that missions can either address the finding of a solution for a given problem or a problem for a given solution[1]. From their perspective, societal views on either problems and solutions can converge vs. diverge depending on a low vs. a high degree of wickedness in terms of contestation, complexity, and uncertainty. Accordingly, a societal challenge can be located in one of four states in the problem-solution space: A societal challenge is either in a state of a. disorientation (problem and solution wickedness high) b. problem in search of a solution (problem wickedness low, solution wickedness high) c. solution in search of a problem (problem wickedness high, solution wickedness low) or d. alignment (problem and solution wickedness low). The authors describe three conceptual pathways for how societal challenges might progress from a state of disorientation to one of alignment via MOP: problem-driven (converging on the problem first then the solution), solution-driven (converging on the solution first then the problem) and hybrid (mixed approach).

Overall, Wanzenböck et al. (2020) were the first emphasize how *debates* on problems and solutions shape directionality of missions over time. These debates may be seen as negotiation processes within communities of actors relevant to the mission. Actors are bargaining problems and solutions by approximating positions on issues, seizing particular roles and responsibilities and contrasting alternative sets of knowledge.

[1] We acknowledge that some authors suggest mission statements based on either problems or solutions (Wanzenböck et al. 2020; Wittmann et al. 2021) while others intend to derive missions from problems and see solutions as part of the subsequent problem-solving process (Reike et al. 2021; Elzinga et al. 2023). We follow the first interpretation.

3. Breaking down the problem-solution space

While the problem-solution space provides a useful heuristic for understanding problems and solutions, it may currently overlook the complex relations of issues in policy-making. Particularly the assumption of a single problem-solution combination that constitutes a societal challenge (i.e. one problem and one solution (or few at most)) with each side experiencing a collective degree of wickedness might not withstand the realities of policy making. Therefore, we seek to develop a refined analytical lens on problems and solutions within societal challenges based on the concept of hierarchies.

3.1. Hierarchies in the problem-solution space

A first observation based also on the empirical variety of missions (Larrue 2021) is the plethora of different kinds of problems and solutions that are potentially constitutive for a mission. A societal challenge may act as an umbrella for assembling different problems and solutions being relevant in this context. In the rise of so-called "transformer missions" that seek to change broader societal systems (Wittmann et al. 2021), missions are required to handle not only technological issues but also a wide array of economic, social, cultural relations and even adjust the political system itself.

Such missions rely on the involvement of a broad set of actors within the relevant innovation system to capture the opinions on the matter at hand (Hekkert 2023). Their contributions of knowledge significantly depend on the power dynamics within the relevant innovation system (Cronin et al. 2024). Positions within respective networks (e.g. the capacity to form coalitions) as well as access to resources affects how actors may shape expectations and visions (Smith et al. 2005). Often these dynamics represent struggles around vested interests that are defended by incumbents against – often weaker – new narratives by entrepreneurial actors (Grillitsch et al. 2019).

As such, it is especially the intentional shaping of discourses and narratives around societal issues that constitute the problem-solution space. These issues not only represent discursive entities but relate to established domains like technological or scientific domains containing sets of actors, knowledge, routines, etc. (Ning & Guo 2022; Balland & Boschma 2022). Narratives may correspond to these domains (e.g. in case of well-established debates for that structures of technologies, infrastructures, etc. have formed), refer to particular parts of them (e.g. if a newly debated issue cuts across established domains) or may subsume issues (like in the case of "circular economy" (Kirchherr et al. 2017) that integrated domains of recycling, refurbishment, etc.).

Furthermore, research has shown that debate on problems and solutions concerns various levels such as the individual-, group-, institutional- or broader societal level and as such affect policies (Shanahan et al. 2013). Therefore, these narratives form structures around the core components of societal challenges. In this regard, one may distinguish two basic ordering principles of vertical and horizontal relationships:

First, aspects may be debated at different levels of specification (vertical perspective), representing levels of abstraction. This is due to the fact that in the context of missions, actors debate aspects of varying granularity depending on their focus (e.g. more vision- as opposed to intervention-focused) (Janssen et al. 2023). Therefore, societal challenges can be seen as multi-level structures in which problems and solutions may consist of lower-level problems

or solutions. Looking, for example, at missions in the circular infrastructure sector, Coenen et al. (2023) distinguish between three different (vertical) levels of solutions, namely solutions as abstract strategies such as reuse or recycle, more specific technological solutions (e.g. bio-based materials), and solutions addressing circular systems in terms of e.g. processual adjustments. These levels relate to one another. For instance, the abstract strategy of repairing may contain more specific technological solutions such as modular design.

Second, issues may not only be debated at different levels of societal challenges but also on equal levels. In this regard, issues are located on similar levels of granularity, representing issues that are not derivative of or subordinate to the other. In the context of missions, this is, for instance, the case if greenhouse gas emissions of different industry sectors (problems) or contributions of different technologies in lowering emissions (solutions) are considered (Bergek et al. 2023).

Building on this distinction of vertical and horizontal relationship, we argue that problems and solutions can be understood as hierarchical structures. In particular, we can distinguish between four types that exhibit different relations and combinations of debated problems and solutions (see Figure 1):
a. problem-hierarchies: problems consisting of further problems (e.g. energy consumption of digital technologies consisting of problems related to devices-, networks-, data center-related energy usage (Bieser et al. 2023))
b. solution-hierarchies: solutions composed of further solutions (e.g. the solution renewable energies composed of solutions from wind, solar, water, etc. (Jacobson & Delucchi 2011))
c. problem-solution hierarchies: solutions to collectively contribute to the solving of a problem (e.g. the mix of policies to tackle obesity-related diseases (Lang & Rayner 2007))
d. solution-problem hierarchies: problems if solved enabling a solution (e.g. social acceptance hindering rollouts of wind turbines (McKenna et al. 2016)).

Figure 1: Hierarchies in the problem-solution space

However, while issues exhibit different types of relationships, debates on societal challenges are usually more complex, so that public discourse on societal challenges results in various multi-layered hierarchies of problems and solutions. On the one hand, problems and solutions within a societal challenge are debated at a multitude of levels with different granularity. Taking the aforementioned case of digitalization-related energy consumption (Bieser et al. 2023) as an example, the problem of energy consumption is not only debated for the whole ICT sector, but also for all end user devices, contributions of particular groups of devices (like monitors) and on an even lower level, subgroups of devices (like LCD monitors).

On the other hand, hierarchies of societal challenges may contain not only connected issues but also further and rather unconnected hierarchies that co-exist parallel to each other. We refer to these parallel structures as *debate strands*. This is, first, because the same or similar problems and solutions are debated from different perspectives. For instance, Garud et al. (2014) suggest that narratives of innovation may take different perspectives for the same object like emphasizing rather static elements (like actors, their attributes, etc.) or describing more from a temporal perspective (like procedural steps or chronologies). Moreover, it may be the case that debated issues are not all connected. Actors might focus on certain problems and solutions but neglect others (e.g. due to requirements of certain groups). This will lead to rather unconnected debate strands within hierarchies.

We further assume that the top and bottom level issues confine the relevant levels of granularity and thereby all as meaningful considered issues (i.e. *scope of debate*). Therefore, we suggest that hierarchies can be characterized by the depth and breadth between these confinements. Depth might refer to the vertical extent to which problems and solutions are debated. A higher number of levels thus reflects a more granular debate on issues. Breadth of debate describes the horizontal extent to which issues are debated. Therefore, breadth captures the overall variety of issues and hierarchies. The deeper and broader a debate on a societal challenge the more aspects can be taken into account and potentially affected by MOP.

3.2. Wickedness and hierarchies

In the previous sections we have highlighted the often complex interplay of problems and solutions in general. Research on MOP has further pointed out that multifaceted issues like societal challenges can be considered as "wicked problems". In general, wicked problems relate to issues of social planning and policy making that are characterized by ambiguity, interconnectedness and lack of clear solutions (Rittel & Webber 1973). A key question is whether the views of relevant actors converge on these structures. Literature on wicked problems suggests that societal views might converge or diverge on societal issues (Alford & Head 2017). More precisely, issues might differ by combinations of contestation, complexity and uncertainty leading to variants between rather tame or wicked issues (Head 2008; Alford & Head 2017).

Looking at wickedness from a hierarchy perspective, we assume that the distribution of contestation, complexity and uncertainty within societal challenges must be taken into account. While this classification of wickedness has been proposed for issues as a whole, it remains unclear how the distinct composition of contestation, complexity and uncertainty affects the wickedness of a societal challenge. From our perspective, for every societal challenge, actors will align on some components, therefore on certain underlying structures of problems and solutions. The moment that a societal challenge becomes politically relevant there must have been a certain amount of debate, leading to the con- and divergence for certain issues. As societal and scientific discourse can zoom in on certain problems and solutions in isolation, any issue or constellation of linked issues within a hierarchy might experience high or low degrees of contestation, complexity or uncertainty. For instance, societal views might converge on the contributions of broader renewable technologies (e.g. contribution of solar energy) while we might still struggle to understand the individual contributions of certain actor groups or social practices.

Consequently, if debates on societal challenges can be explained as multi-layered hierarchies in which societal views can con-/diverge to varying degrees for individual issues, we suggest that the highest-level problem or solution that societal views converge on can be interpreted as the narrational label of the societal challenge itself. As such, it frames all relevant issues and, therefore, the hierarchies below. This is in line with Janssen et al (2023) who describe how missions might be seen as meta-narratives for policy issues at the highest level of abstraction. From a MOP perspective, we thus assume that any problem or solution which frames hierarchies with diverse economic, technological, socio-cultural and political issues in a particular context of a mission can be considered a societal challenge.

3.3. Temporality in hierarchies

MOP-related literature has pointed to the fact that problems and solutions are continuously reinterpreted over time. This situation has been referred to as the "problem-solution dance" (Rohracher & Ornetzeder 2024). It seems clear that in the same way as issues rise in public debate, the hierarchies they form may change as well. This is driven by public debates, agenda setting, new technological developments, etc. More particularly, hierarchies may emerge, fade or remain stable over years. Additionally, not all will evolve similarly with regards to the underlying wickedness. Hierarchical relations might shift more towards or move back from convergence over time (e.g. when new debates reach MOP initiatives leading to new goals). As empirical research has shown, even changing periods of convergence and divergence are possible within a particular mission (Brett et al. 2023).

Moreover, the aforementioned manifestations of temporality in hierarchies may follow certain patterns: First, the changes described may vary in terms of origin within hierarchies. For instance, Prochaska and Schiller (2021) show how as part of a mission the discursive focus shifted from the issue of biotechnology to a more holistic narrative of a bioeconomy. Thus, changes in debates may originate from certain hierarchical levels and follow a bottom-up (as in the described example) or top-down logic. Second, the pace of change might differ on the various levels of hierarchies. It has been shown that in missions on some levels societal views can converge more rapidly than on others (e.g. if consensus forms more quickly for certain tools but not for overarching strategies) (Coenen et al. 2023).

3.4. Leverage points for mission design and the problem-solving process

As Wanzenböck et al. (2020) have argued, wickedness as well as temporality might guide decisions in MOP. However, based on the perspective of hierarchies, leverage points for missions might also come about through the way issues are debated on different levels. In the following section, we will elaborate on how the theoretical perspective of hierarchies may be used to reflect on priority setting in missions. Identifying the right *leverage points* (i.e. concrete issues to focus on in MOP) in hierarchies might be crucial for directionality. We differentiate between leveraging vertical vs. horizontal fragments of hierarchies.

3.4.1. Leverage points with a vertical focus

Two cases of leverage points might be interpreted as a chance to take advantage of promising vertical relations in MOP: a. *high impact issues*: Problems or solutions might offer substantial individual contributions to higher-level issues relative to other issues on the same level. If, for instance, a region within a state shows the greatest share of overall emissions compared to other regions, it might be promising to focus a mission on that particular issue b. *missing piece issues*: Issues might be the final piece to a puzzle of solving a societal challenge. For instance, missions could promote the development of a particular technology that promises a breakthrough in battling a particular health-issue. Figure 2 illustrates these instances in a stylized manner. Examples of such issues are shown in Table 1 for all four types of hierarchies.

Figure 2: High impact and missing piece issues

Table 1: Examples of high impact and missing piece issues

3.4.2. Leverage points with a horizontal focus

We further differentiate between two cases of leverage points with a horizontal focus: a. *cross-cutting issues*: one issue is a relevant component of several issues on a higher level. For instance, artificial intelligence might hold relevant solution potential for various SDGs (Vinuesa et al. 2021) b. *complementing issues*: From a different angle, one issue might rely on the same issues on lower levels as another issue e.g. if a technology requires the same infrastructure as another. Both of these issues might thus represent synergies between issues expressed in, for instance, spill-over effects and serendipitous discoveries (Mazzucato 2021) (in the case of solutions) or concurrent mitigating effects along issues (in the case of problems). Figure 3 shows stylized depictions of these instances. Examples of such issues are shown in Table 2.

Figure 3: Cross-cutting and complementing issues

Table 2: Examples of cross-cutting and complementing issues

3.5. The mission firmament

In the previous section, we have elaborated on the structural characteristics of the relations between problems and solutions within a societal challenge, highlighting the importance of hierarchies, wickedness, temporality and leverage points in directing missions. These building blocks can be brought together to form an overall analytical framework. As an allegory for our concepts, we use the idea of the firmament of stars that can guide sailors towards the right route as MOP will have to prioritize and decide upon issues to tackle. The "mission firmament" represents the sum of constellations of problems and solutions debated within a societal challenge in a stylized framework (see Figure 4):

Figure 4: Mission firmament

In the mission firmament, problems (P) and solutions (S) are depicted as boxes. These build hierarchies due to issues being nested within one another (i.e. issues consisting of further issues on lower levels or contributing to issues on higher levels). This is shown as lines engulfing the boxes. Larger boxes express more relevance for the overarching topic as opposed to smaller ones. The issue at the very top represents the societal challenge that frames the related discourse as a meta narrative. Below it, several hierarchies are shown in distinct debate strands that visually support the fact that actors might set differing foci of debate as well as describe issues in varying terms. Debate is further confined by the depth (y-axis) and breadth (x-axis) which portray the scope of relevant discourse within a societal challenge. Moreover, the degree of wickedness (contestation, complexity and uncertainty) is displayed for each issue as low (dark gray), moderate (gray), high (light gray) as societal views do not con- or diverge for all issues equally. In order to account for changes over time, issues might emerge (↑) or fade (↓) from the scope of debate as well as experience shifts in con- or divergence with an ongoing increase (+) or decrease (-) of alignment. In addition, the mission firmament shows leverage points as issues to potentially focus on in mission design as well as the problem-solving process. These are visualized as outlined boxes.

4. Illustrative example of the circular economy in Germany

In this section, we seek to illustrate the applicability of the mission firmament with the case of the circular economy in Germany. Circular economy relates to an economic system in which the "end-of-life" of products and materials is countered with so-called r-strategies (e.g. refurbish, reuse, etc.) to increase lifespans and close loops (Kirchherr et al. 2017). In December 2024, the national strategy for circular economy (German: "Nationale Kreislaufwirtschaftsstrategie" (NKWS)) by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) was adopted (BMUV 2024a). The strategy calls for a mission-oriented implementation even though it is yet to be determined how to operationalize the mission-oriented approach.

As the main umbrella strategy for Circular Economy in Germany, the NKWS provides a good case to explore the validity of our framework. That is because the strategy document contains a consolidated overview of relevant problems and solutions and represents the current state of the mission. The NKWS is supposed to bring together objectives and measures for circular economy and resource conservation from other related strategies in Germany (such as the German raw materials strategy or the national bioeconomy strategy) and has thematic links with other strategies (e.g. the Future Research and Innovation Strategy).

The strategy seeks to reduce per capita consumption of primary resources to six to eight tons per capita per year and contains three specifically formulated goals with regards to 1. material cycles 2. resource sovereignty and supply security and 3. waste prevention. The strategy details measures in twelve prioritized fields of action (such as circular production, textiles or international cooperation) as well as eleven cross-sectional topics (like product design or skill development).

The NKWS was developed in a multi-stakeholder process over about a year starting early 2023. Two top level fora, four dialogue workshops, round tables for each prioritized field of action were combined with an online participation process (BMUV n.d.) and more than 120 public statements by organizations were integrated (BMUV 2024b). Ensuring broad participation of various actors, the process integrated perspectives from politics, business, science and civil society (BMUV 2023).

In order to illustrate our conceptual framework, we focus on the "digitalization and circular economy" field of action as an example. It is the first described field in the strategy and called a key prerequisite for implementing a circular economy in Germany. Additionally, digitalization may affect various sectors and value chains thus calling for the strengths of MOP in cross-sectoral and interministerial collaboration. By analyzing this field of action in detail and linking it to the overarching goals of the strategy, we strive to exemplify hierarchies with a thorough understanding of problems and solutions from the highest to the lowest levels of abstraction.[2]

[2] In line with our conceptualization of parallel debate strands, we acknowledge that some digitalization issues can also be found in other fields of action (like the digital product passport being recommended for wind turbines in the field of renewable energy systems). From our perspective, these parallel issues are embedded in different debates by different communities. They might thus experience similar but also varying degrees of di-/convergence.

In order to assess hierarchies of issues, we conducted a qualitative text analysis of the field of action in the main strategy document. To assess our key concepts (particularly problems, solutions and hierarchical relations), we followed a structural coding approach that allows to explore text-data based on conceptual phrases i.e. allocating text to codes that represent predefined concepts (Saldaña 2013). We developed a codebook in that we operationalized issues (problems and solutions) and hierarchies (vertical and horizontal) assuming explicit and implicit mentions of our concepts (see online appendix). To grasp wickedness and temporality, we draw on additional sources debating the circular economy in Germany. The following results could be derived based on the building blocks of the mission firmament (see Figure 5):

a. *Societal challenge:* Germany has a long tradition in recycling (Nelles et al. 2016) but debates shifted more towards a holistic understanding of circularity thus targeting the full arsenal of r-strategies. The NKWS has incorporated this perspective and addresses the broad societal challenge (i.e. top level problem) of consumption of primary resources with the directly underlying problems of unclosed material cycles, weak resource sovereignty and supply security as well as the amount of municipal waste. Accordingly, the strategy addresses not only waste loss and waste management but also lifetime extension.

b. *Debate strands and scope of debate:* While the separation of the broader challenge by fields of action in itself represents a compartmentalization, the "digitalization and circular economy" field contains subsections such as "Digitalization for climate and resource protection in design and production". This structure leads to a rather isolated view on relations between problems and solutions within but not across these subsections. Furthermore, compared to earlier policy strategies involving digital technologies to increase circularity (e.g. digital policy agenda for the environment (BMUV 2020)), the strategy shows significantly greater depth and breadth, thus scope of debate.

c. *Relations between issues:* German stakeholders had a clear understanding of the need to approach the hierarchical structures of issues in the circular economy in order to "identify and break down barriers to innovation" for a circular economy (Weber & Stuchtey 2019). The NKWS incorporates that view - even though not explicitly - as problems and solutions are addressed on various levels. At the higher levels, the core problems and solutions in the field of action (like r-strategies or circular business models) contribute to the overarching problems (e.g. limiting primary material use to 8 tons per capita by 2045) of the strategy. Each of these core issues is linked to a prioritized issues at lower levels constituting solution-hierarchies (e.g. r-strategies and circular design), problem-solution hierarchies (e.g. material loss and end-of-life processes) and solution-problem-hierarchies (sustainable circular consumption and impacts of online retail). These hierarchies are linked to the problem of transparency of products and materials that is supposed to be solved with the digital product passports and data spaces.

d. *Wickedness of issues:* While particularly the overarching goal of lowering primary resource consumption was pushed by some and contested by other actors (high contestation), German industry associations (The Federation of German Industries (BDI) 2024a; The German Engineering Federation (VDMA) 2024; The Association of the Chemical Industry (VCI) 2024) as well as civil society actors (e.g. Germanwatch 2023) broadly support the application of digital technologies for circularity with varying positions only on minor aspects (low contestation). Similarly, position papers on selected issues (like the contributions of digital product passport and data spaces) have been published demonstrating

general understanding of core issues and roles without describing implementation in detail (e.g. BDI 2024b) (moderate complexity). However, issues differ significantly with regard to their knowledge base affecting the degree of uncertainty: Relevant macro-level data on the overarching issues of the NKWS has been published (Tauer & Aechtner 2023). Research initiatives have depicted the relevance of digitalization for circular consumption (Lell et al. 2020). Moreover, practical knowledge is provided on how digitalization fosters business model innovation (Circular Economy Initiative Deutschland 2021). And the state of digital transformation in the German waste management sector has been outlined comprehensively (Office of Technology Assessment at the German Bundestag (TAB) 2023). Additionally, various German research institutes assess the potentials of transparency for circularity (Neligan et al. 2023; Götz et al. 2023) (low uncertainty). On the other hand, while the relevance of design processes for r-strategies is known in German debate (Piétron et al. 2023) more detailed contributions are missing. And as in the international context (Medaglia et al. 2024), research measurability and digital governance for the circular economy is scarce also in Germany (high uncertainty).

e. *Temporality*: Digitalization and circular economy might overall be understood as a rather new topic emerging recently (Chauhan et al. 2022). However, some issues experienced a more pronounced increase in debate: Discussions on digital circular consumption are currently increasing with first application-oriented projects being initiated (BMUV 2024c). Additionally, surrounding the issue of transparency and the digital product passport, activities intensify with, for instance, data requirements being defined as part of the ecodesign for sustainable products regulation (European Commission 2024) and the establishment of new standardization committees (Deutsches Institut für Normung (DIN) 2023). On the other hand, several issues are under constant consideration over the last years like r-strategies (e.g. decision making assistants (Mügge et al. 2022)), business models (e.g. software-as-a-service models (Heinig 2023)) and waste management (TAB 2023). Through stakeholder participation, all issues should have experienced – to a certain degree – an increase in convergence of stakeholder views during 2023.

f. *Leverage points*: The mission firmament further allows for a careful consideration of potential leverage points to focus on in missions[3]. It is particularly the transparency of products and materials that might be interpreted as *cross-cutting issue*. Prioritizing this element in missions would potentially have positive implications for various solutions at a higher level (e.g. enabling user-friendly information, etc.) and thus contribute to solving the overarching problems defined in the NKWS. It might as well be promising to focus on these higher-level solutions as they could represent *complementing issues*. Addressing, for instance, evaluation of material use could "pull" a solving of the transparency issue and thus affect other issues.

Finally, the visualization of hierarchies gives further insights on aspects to look after when designing and implementing programs: a. The "digitalization and circular economy" field of action seems to have a solution focus with several solution- and solution-problem-hierarchies presented. This could be extended with a thorough problem understanding b. Some contributions between levels remain vaguely described (e.g. how transparency adds to the

[3] To our best knowledge, the NKWS and relevant literature regarding digitalization and circular economy does not allow a quantitative assessment of problems or solutions. Thus, potential *high impact issues* are difficult to spot. Similarly, due to the rather young debate (Pagoropoulos et al. 2017), missing piece issues are challenging to identify.

enablement of artificial intelligence tools, better waste separation, etc.). Such links could benefit from further clarification (e.g. by adding detailing layers) c. The NKWS does not elaborate on whether issues are addressed comprehensively and it does not explain their additionality. The mission could seek to ensure that all parts within broader issues are contained and issues are prioritized that independent market mechanisms or established policy measures do not regard.

Figure 5: Mission firmament of the NKWS in Germany

5. Discussion

5.1. Extending the conceptualization of the problem-solution space in MOP

In this conceptual paper, we explored the relations of problems and solutions underlying societal challenges as a key reference point for MOP. We develop the mission firmament framework as a new analytical lens showing hierarchies of problems and solutions within societal challenges. Grounding our conceptualization in the influential problem-solution space (Wanzenböck et al. 2020), we argue that an extended perspective is necessary:

First, in many instances, societal challenges will require a combination of different solutions for addressing multiple problems simultaneously. From our perspective, single problem-solution combinations that constitute a societal challenge in the problem-solution space (i.e. one problem and one solution (or few of each at most)) could represent preselection and potentially lead to an exclusion of relevant issues in the analysis of missions. This is in line with, for instance, literature on broad policy mixes that are needed for triggering technology push as well as demand pull mechanisms (Rogge & Reichert 2016) and the extension of technological developments with social innovations to comprehensively tackle societal issues (Edler et al. 2024). Consequently, even though a core characteristic of missions is their pursuit of a concrete goal, researching directionality of missions requires a more multidimensional understanding of decisions on problems and solutions.

Second, we find that societal views may con-/diverge on the many relevant problems and solutions individually. Thereby, the so called "problem-solution dance" (Rohracher & Ornetzeder 2024) might be more complex than currently displayed in the problem-solution space. Wanzenböck et al. (2020) assume a collective degree of wickedness for each problems and solutions. Thus, societal challenges move through the problem-solution space along three pathways until societal views converge for all issues (low degree of wickedness for both problems and solutions). Contrasting this view, we suggest individual issues to experience con-/divergence and also entire sets of issues within societal challenges to be in constant movement. This calls into question the simplified understanding of pathways through the problem-solution space. Our insights rather point to the relevance of analyzing how societal views converge around diverse issues in parallel and making the co-evolution of adjacencies transparent.

Third, from our perspective, a societal challenge is a converging problem or solution itself. As such, it represents a narrational label framing further underlying problems and solutions that may be interpreted as specifications of the societal challenge (e.g. national emissions being composed of emissions of several regions). In the problem-solution space, however, problems and solutions are two opposite sides without any detailed conceptual link to what constitutes a societal challenge. This leads to inconsistencies in the analysis of missions: If societal views converge neither on problems nor solutions or in case convergence decreases for one side while it increases for the other, we would not be able to define a societal challenge. Our conceptualization, however, takes into account how underlying issues experience di-/convergence rather independently without necessarily affecting the overarching societal challenge. Shifts of the narrational frame (i.e. the societal challenge) on the other hand must almost always induce movements in the issues below. Thus, a clear differentiation between the societal challenge and the underlying issues seems highly relevant for analyzing directionality in MOP.

Fourth, we argue that some converging issues might be more promising to focus on in missions than others. More precisely, if a problem or solution is of higher importance to solving the societal challenge than others, missions may profit from targeting these aspects of a societal challenge. For Wanzenböck et al. (2020), the key rationale for directional decisions in MOP follows the position of a societal challenge in the problem-solution space (e.g. focusing on clarifying the solution side if societal views already converged on the problem). Therefore, going beyond the idea of matching converging problems and solutions, we emphasize the need to understand relative impacts of converging issues and their leveraging capacities.

5.2. Further research

While we advanced the conceptualization of problems and solutions in the context of MOP, further research is needed to improve the understanding of directionality related decision making.

First, proposing the mission firmament as a framework to depict problem-solution hierarchies, we take a rather static perspective describing problem-solution relations at a certain point in time. From this perspective, the framework could be linked to questions about the emergence of hierarchies. We touched the matter of how actors contribute knowledge to the debate on problems and solutions without detailing such processes. Further studies could delve deeper into the determinants and context factors of the hierarchies we conceptualized. This could, for instance, regard the role of power, institutional structures and rules or cultural settings in shaping debates on problems and solutions.

Second, a core contribution of the problem-solution space has been the description of pathways for missions to move towards problem-solving (Wanzenböck et al. 2020). As argued in our framework, problem-solutions are more complex and dynamic, therefore challenging the explanatory power of the three stylized impact pathways described by Wanzenböck et al. (2020). Empirical research following the example of Brett et al. (2023) could contribute to better understand what kind of pathways exist with regard to hierarchies and whether one can derive any general patterns for movements.

Third, the framework so far does not explicitly take into consideration the pace of change in hierarchies. On the one hand side, this could relate to debate itself (i.e. the pace of how topics enter debates or fade from them) as well as alignment (i.e. processes of con-/divergence). For instance, from an empirical perspective, it might be worthwhile to study, how exogenous shocks affect the mission firmament and hierarchies in comparison to gradual change processes.

6. Conclusion

Analyzing directionality in MOP requires a thorough understanding of problems and solutions underlying a societal challenge. We conceptualize the mission firmament framework which shows hierarchies of debated problems and solutions within societal challenges, the dynamics involved and the promising constellations of issues that may guide decision making in MOP. We illustrate our framework by applying the mission firmament to the exemplary case of the circular economy in Germany. The following key insights have been developed:

The relationships between different sets of problems, sets of solutions and between problems and solutions can be described by vertical and horizontal relations. Such hierarchies thus depict debates on issues on different and equal levels of specification. Whereas vertical relations reflect a nesting or contributions of issues (like a technological solution consisting of infrastructures, skills, etc.), horizontal relations represent the co-existence of a variety of issues on similar levels of abstraction (e.g. in case environmental impacts of various sectors or technologies are compared). Additionally, these structures build various multi-layered hierarchies within societal challenges as parallel debate strands are formed through actors with different perspectives and foci. As a whole, every societal challenge might be characterized by a certain scope of debate with particular depth and breadth.

Moreover, we incorporate key peculiarities of MOP (wickedness and temporality) in the framework. As actors can debate particular sets of issues in isolation, societal views might converge on some issues but diverge on others. Thus, the degree of contestation, complexity and uncertainty may differ for respective components of hierarchies. Also, debates experience shifts over time as issues emerge or fade and alignment increases or decreases. As a result, structural changes around problems and solutions turn hierarchies – thus societal challenges – into dynamic systems with moving targets for MOP.

In addition to these theoretical aspects, we find that also practitioners – in terms of mission design as well as the process of problem-solving – might benefit from our conceptual perspective. That is, missions seem to implicitly deal with hierarchies of problems and solutions to direct innovation processes towards higher level issues. In policy practice, the mission firmament can help structure development processes and make dependencies as well as implicit assumptions visible. This allows tracing converging problems and solutions and identifying promising leverage points as guiding stars for setting direction in missions.

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Figure/table legends

Figure 1: Hierarchies in the problem-solution space

Figure 2: High impact and missing piece issues

Note: Problems and solutions (boxes); wickedness of issues (high (light gray) and low (dark gray)); relevance of issues for the overarching topic (size of boxes (increasing size represents higher relevance)); leverage points (outlined boxes).

Figure 3: Cross-cutting and complementing issues

Note: Problems and solutions (boxes); wickedness of issues (high (light gray) and low (dark gray)); leverage points (outlined boxes).

Figure 4: Mission firmament

Note: Problems and solutions (boxes); wickedness of issues (low (dark gray), moderate (gray), high (light gray)); relevance of issues for the overarching topic (size of boxes (increasing size represents higher relevance)); change in debate (emerging (↑), fading (↓)); change in wickedness (increasing (+), decreasing (-)); leverage points (outlined boxes).

Figure 5: Mission firmament of the NKWS in Germany

Note: Problems and solutions (boxes); wickedness of issues (low (dark gray), moderate (light gray)); relevance of issues for the overarching topic (size of boxes (increasing size represents higher relevance)); debate strands (separated hierarchies); change in debate (emerging (↑), fading (↓)); change in wickedness (increasing (+), decreasing (-)); leverage points (outlined boxes).

Table 1: Examples of high impact and missing piece issues

Table 2: Examples of cross-cutting and complementing issues

	High impact issues	**Missing piece issues**
Problem-hierarchies	Plastic pollution as most relevant factor in leaving the safe operating space of the novel entities planetary boundary (Persson et al. 2022)	Approaching contaminated water in the context of cholera outbreaks as a game changer (Smith 2002)
Solution-hierarchies	Dietary shifts as one of the most critical demand-side solutions for reducing emissions in agriculture (Creutzig et al. 2016)	The Clean Air Act Amendments of 1990 in the US as most relevant measure for reducing acid rain rather permanently (Menz & Seip 2004)
Problem-solution hierarchies	Water purification technologies (like reverse osmosis) with a particularly high impact in solving water scarcity (Van der Bruggen 2015)	Establishment of a large scale vaccination campaign for eradicating smallpox (Henderson 2011)
Solution-problem hierarchies	High costs as substantial factor in scaling carbon capture and storage (Rubin et al. 2015)	Insufficient energy storage capacities that if provided promise breakthrough of renewable energy supply (Kittner et al. 2017)

Table 1: Examples of high impact and missing piece issues

	Cross-cutting issues	**Complementing issues**
Problem-hierarchies	E-Waste as contributing to several issues such as toxic pollution but also issues related to public health (Forti et al. 2020)	Addressing deforestation can also mitigate soil erosion, as both issues are often driven by unsustainable land use practices (Bruijnzeel 2004)
Solution-hierarchies	Smart meters enabling not only sustainable decisions of consumers but also load management in decentralized energy production (Darby 2010)	Electric vehicles relying on smart grids just as decentralized solar energy (Gielen et al. 2019)
Problem-solution hierarchies	Universal basic income could potentially impact various social and economic problems (Hoynes & Rothstein 2019).	Targeting urban heat islands can synergize with emission reduction as both can profit from greening cities (e.g. reduced air conditioning) (Akbari et al. 2016)
Solution-problem hierarchies	Socio-economic disparities hindering the adoption of several sustainable practices and technologies by less affluent communities (Sovacool & Dworkin 2014)	Offshore wind shares the barrier of hindering permitting processes with tidal energy technologies (Buck & Langan 2017)

Table 2: Examples of cross-cutting and complementing issues

Figures

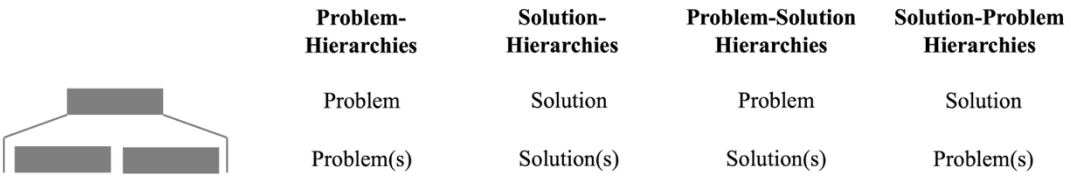

Figure 1: Hierarchies in the problem-solution space

Vertical focus:

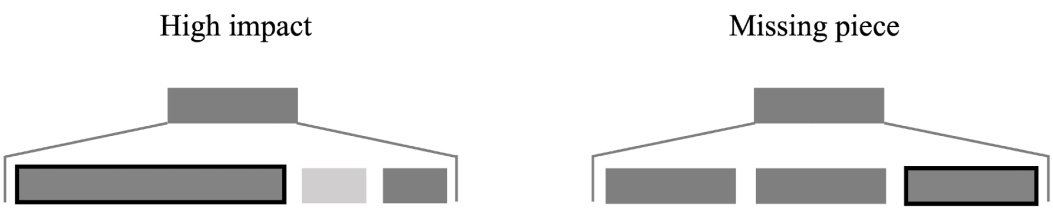

Figure 2: High impact and missing piece issues

Horizontal focus:

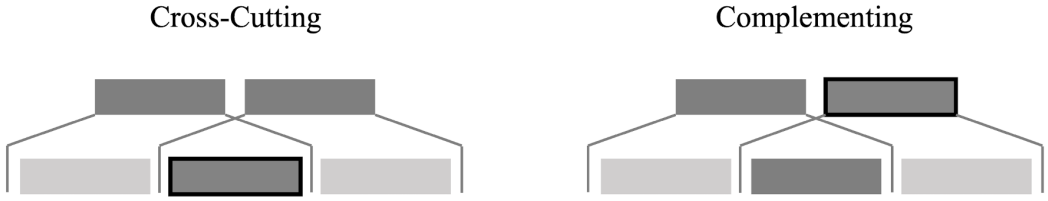

Figure 3: Cross-cutting and complementing issues

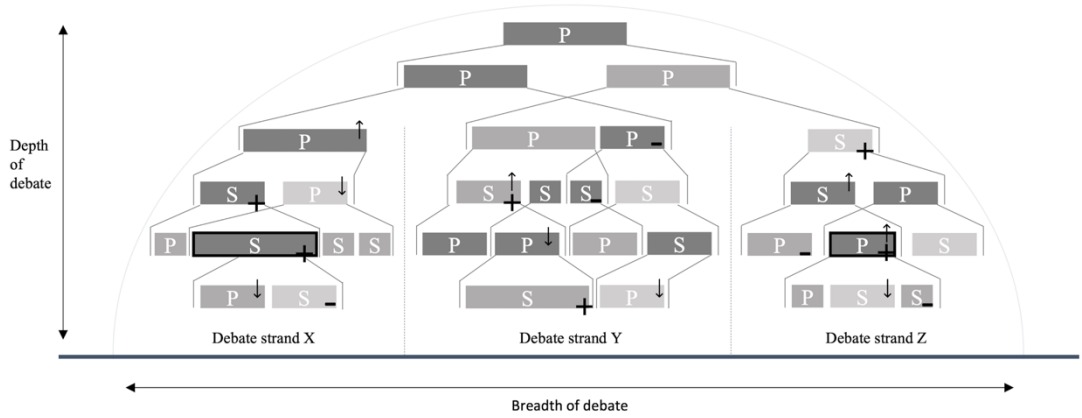

Figure 4: Mission firmament

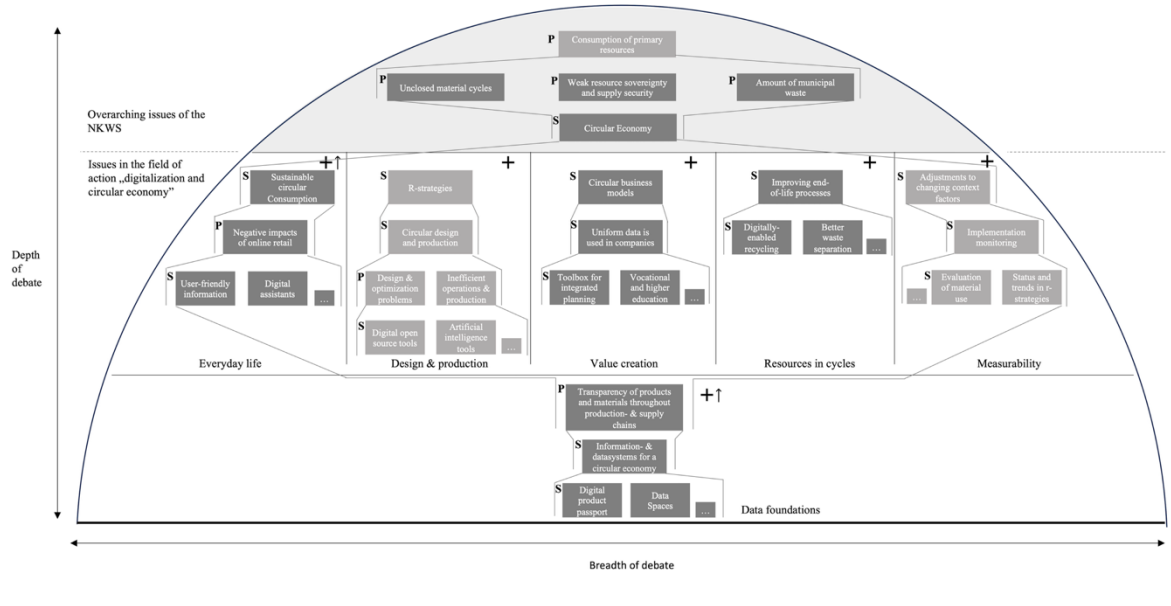

Figure 5: Mission firmament of the NKWS in Germany

Online Appendix

Authors & Year	Application	Details
Allan et al. 2023	Reference in explanation	Indicating that the movement of a societal challenge through the PSS might be hindered or enabled under certain conditions that relate to agency, boundaries and inter-temporality.
Borrás & Schwaag Serger 2022	Partial application as part of broader framework	Comparing challenge-oriented R&I-programmes in terms of their processes for achieving problem and solution directionality.
Bours et al. 2021	Reference in explanation	Referring to a wickedness perspective (e.g. complexity and uncertainty) when describing the problem context of pollution in Dutch waterways.
Brett et al. 2023	Detailed application	Comparing problem and solution movements from the perspective of translating global challenges into local contexts.
Bugge et al. 2021	Detailed application	Exploring how established innovation systems may interact with problems and solutions as part of missions.
Coenen et al. 2023	Reference in explanation	Proposing for a circular infrastructure case that problems as well as solutions face significant wickedness due to substantial contestation
Dorji et al 2021	Detailed application	Giving a detailed overview of converging/diverging problems and solutions in the field of sustainable agriculture (case: yak farming).
Elzinga et al. 2023	Reference in framework building	Building a framework for assessing a mission-oriented innovation system with problem as well as solution directionality.
Kehl et al. 2021	Reference in explanation	Recommending that the Office of Technology Assessment at the German Bundestag (TAB) should map potential policy pathways through the problem-solution space.
Lehoux et al. 2023	Reference in explanation	Suggesting that a mission-oriented policy approach could help set priorities in health-related innovation issues by addressing contestation, complexity and uncertainty.
Reike et al. 2022	Partial application as part of broader framework	Describing problem- and solution-directionality for the case of circular textiles in the Netherlands as component in a Mission-Oriented Innovation System
Rohracher & Ornetzeder 2024	Reference in explanation	Describing how a mission-oriented programme started in alignment but moved backwards in the PSS as more problems as well as solutions became debated
Uyarra et al. 2023	Reference in framework building	Building a framework for differentiating between problem and solution representations from a local vs. global perspective
Wiarda et al. 2023	Operationalization of the framework	Setting up a systemic approach for assessing problems and solutions as part of societal challenges
Wittmann et al. 2021	Reference in framework building	Conceptualizing accelerator vs. transformer missions as either problem- or solution-oriented
Wojtynia et al. 2021	Detailed application	Analyzing converging/diverging problems and solutions in sustainable agriculture (case: Dutch agri-food systems).

Table 1: Application of framework Wanzenböck et al. (2020) (own elaboration)

Codebook		Reference Category	
		Explicit	**Implicit**
Societal Issues	**Problems**	Issues directly identified as undesirable, harmful, or in need of a resolution (e.g. mentioning as "problematic", "harmful", etc.)	Issues contextualized as undesirable, harmful, or in need of resolution (document-based: e.g. "Companies struggling with…" or "Indicator did not reach the targeted value"; domain-based: e.g. uncontextualized mentions of GHG-Emissions)
	Solutions	Issues directly described as (potentially) leading to the solving of a problem (e.g. issues that can "solve" a problem or issues called "solutions").	Issues contextualized as (potentially) leading to the solving of a problem or representing an improvement of a state (document-based: e.g. "is crucial for", "can improve"; domain-based: e.g. deriving that "circular design" is an often debated approach for improving circularity)
Hierarchies	**Vertical**	Directly identified instances of related issues on different levels of granularity and specification (e.g. specifications ("such as" or "encompassing"), causal links ("contributes to"), mentions of "levels"))	Contextualized instances of related issues on different levels of granularity and specification (document-based: e.g. if a section contains a problem debate followed by a list of measures) or headlines representing broader topics that are detailed in the related text; domain-based: description of two issues that can be referred to as being embedded by applying domain knowledge (e.g. if renewable energies (higher level) as well as wind energy (lower level) are debated without explicit connection) but can be linked via domain-specific knowledge.
	Horizontal	Directly identified instances of related issues on equal levels of granularity and specification (e.g. clear descriptions of complementarity or collective contributions as well as clear comparisons (e.g. tables) and enumerations)	Contextualized instances of related issues on equal levels of granularity and specification (document-based: similar syntactic or rhetorical formats e.g. comparable argumentation style; domain-based: e.g. if two issues are often compared in discourse within a topic area

Table 2: Codebook for core concepts