A framework to identify and coordinate responsibilities in industrial research and innovation

Sonck, M.M.

DOI
10.4233/uuid:df45d4e5-0504-470e-b7e6-0fa3d5231709

Publication date
2023

Document Version
Final published version

A framework to identify and coordinate responsibilities in industrial research and innovation

Dissertation

for the purpose of obtaining the degree of doctor

at the Delft University of Technology

by the authority of the Rector Magnificus prof. dr. ir. T.H.J.J. van der Hagen

chair of the Board of Doctorates

To be defended publicly on

Wednesday 8 February 2023 at 10:00 o'clock

by

Matti Markus SONCK

Master of Science (Technology)

Aalto University School of Chemical Engineering, Finland

born in Salo, Finland

This dissertation has been approved by the promotor.

Composition of the doctoral committee:

Rector Magnificus	Chairperson
Prof. dr. P. Osseweijer	Delft University of Technology, promotor
Dr. L. Asveld	Delft University of Technology, promotor

Independent members:

Prof. dr.ir. I.R. van de Poel	Delft University of Technology
Prof. dr. P. Shapira	University of Manchester, UK
Dr. V. Blok	Wageningen University
Dr. H.I. Wikberg	Fortum Power and Heat Oy, Finland
Prof. dr.ir. L.A.M. van der Wielen	Delft University of Technology, reserve member

Other members:

Dr. L. Landeweerd	Radboud University

The research for this thesis was performed at the Biotechnology and Society group, Department of Biotechnology, Faculty of Applied Sciences, Delft University of Technology, Delft, the Netherlands.

The research reported here was partially supported by the EU's FP7 research and innovation programme SYNENERGENE (grant agreement No 321488), and by Paulo Foundation (ID 0116787-3).

Table of Contents

Summary

This doctoral thesis investigates the concept of responsibility in the setting of industrial research and innovation (R&I). Companies have multiple responsibilities in society: profit generation for shareowners, legal and contractual liabilities, as well as socially and morally binding obligations beyond legal compliance. These responsibilities co-exist in R&I, and at times, stand in conflict with each other. Moreover, the radical uncertainty of innovation activity raises dilemmas with regard to responsibility. For instance, can R&I practitioners be held responsible for those future impacts of their innovation that still remain unknown at the time of R&I? Furthermore, how should such responsibility be distributed between developers (R&I), enablers (funders, regulators) and appliers (users) of the innovation?

To address such questions, the broad notion of responsibility first needs to be opened up, to distinguish between its different meanings and elements. This thesis develops a framework that supports identification and coordination of various responsibilities in the inherently uncertain R&I settings. The main research question of the thesis is: *How do different elements of responsibility become identified and carried out in R&I?* As outcome, this thesis will present a *meta-responsibility map*: A tool for industrial R&I teams and consortia to reflect on their responsibilities, in situations such as goal-setting, problem-solving, decision-making, and stakeholder interaction.

Chapter 1 depicts the societal problem motivating this work: the challenges that uncertainty of innovation poses on attempts to govern and control its outcomes and broader societal impacts. The key reference literature, that on Responsible Research and Innovation (RRI), is presented, followed by the introduction of the main research question and the overall approach of this thesis.

Three research papers providing answers to the main research question are presented in Chapters 2–4. **Chapter 2** introduces a responsibility framework that itemizes the extensive notion of responsibility into four elements: care, liability, accountability, and responsiveness. By case-studying an R&I project in the emerging sector of bioeconomy, this theoretically constructed framework is developed further into a *meta-responsibility map* with practical applicability. The meta-responsibility map brings various co-existing (and sometimes contradicting) principles, expectations and obligations under common

terminology – responsibility – and from thereon supports their alignment in the R&I settings.

Chapter 3 further develops the meta-responsibility mapping approach to be applicable in multi-actor R&I networks. Today's industrial R&I often involves multiple industrial and academic participants working as a consortium. While developing novel technologies and materials, these networks are also about reformulation of industrial value chains. By exploring two bioeconomic case studies, Chapter 3 first identifies critical reasons that complicate allocation of responsibilities in emerging bio-based value chains – in particular when it comes to adverse indirect impacts. Next, meta-responsibility map is further enriched to support allocation of responsibilities among participants and stakeholders of R&I: among industrial innovators, regulators and policymakers, as well as civil society representatives such as end consumers.

Chapter 4 delves deeper into *responsiveness*, a responsibility element that appears particularly decisive for R&I as a proactive mindset that supports working under uncertainty. In practical R&I work in the private sector, the idea of responsiveness, as presented in RRI literature, is challenged in many ways. In particular, the idea of "mutual responsiveness" between innovators and societal stakeholders appears problematic. Reviewing extant RRI literature on responsiveness, including theoretical studies as well as three industrial case studies, Chapter 4 proposes "creative approaches" for R&I to become responsive to societal needs and stakeholders.

In **Chapter 5**, the overall conclusions are presented as an answer to the main research question. It is concluded that responsible innovation requires coordination of several co-existing strategies to manage uncertainty of innovation. In the approach of this thesis, these strategies are presented under the four responsibility elements of *care* (values and norms as guideline), *liability* (legal/contractual requirements as guideline), *accountability* (evaluation of impacts) and *responsiveness* (learning-whilst-doing). For each element, it is summarized what their implementation demands of R&I practitioners, and who in the R&I networks should take part in their implementation, for innovation to be considered responsible. Next, the meta-responsibility mapping approach is presented in its final format, including guiding questions that are designed to trigger discussion about the responsibility elements at stake in different decision-making, planning, and problem-solving situations of R&I.

The presented meta-responsibility map is designed to make tensions between the varying responsibilities faced by R&I tangible objects of discussion, and from thereon support their management. Although developed to large extent in the bioeconomic context, this approach can be of interest also in other industries experiencing societal issues related to e.g. environmental sustainability and ethical issues in value chains. Among others, the approach can support alignment of profit-oriented goals with those of addressing global environmental challenges. When applied at early R&I stage, meta-responsibility can also support anticipation of future responsibilities and choice situations that may come about at R&I later stages closer to commercialization. When applied in multi-actor R&I settings, meta-responsibility addresses the risk of "responsibility dilution" between value chain participants. Finally, the systematic approach on responsibility developed in this thesis can increase the theoretical solidity and practical relevance of RRI as an innovation governance and management approach.

Samenvatting

Dit proefschrift onderzoekt het concept van verantwoordelijkheid in de setting van industrieel onderzoek en innovatie (O&I). Bedrijven hebben meerdere verantwoordelijkheden in de samenleving: winst genereren voor aandeelhouders, wettelijke en contractuele verplichtingen, evenals sociaal en moreel bindende verplichtingen die verder gaan dan wettelijke naleving. Deze verantwoordelijkheden bestaan naast elkaar in O&I en staan soms in conflict met elkaar. Bovendien roept de radicale onzekerheid van innovatieactiviteit dilemma's op met betrekking tot verantwoordelijkheid. Kunnen O&I-beoefenaars bijvoorbeeld verantwoordelijk worden gehouden voor de toekomstige effecten van hun innovatie die op het moment van O&I nog onbekend zijn? Bovendien, hoe moet een dergelijke verantwoordelijkheid worden verdeeld tussen ontwikkelaars (R&I), ondersteuners (financiers, regelgevers) en uitvoerders (gebruikers) van de innovatie?

Om dergelijke vragen te beantwoorden, moet eerst de brede notie van verantwoordelijkheid worden ontsloten, om onderscheid te maken tussen de verschillende betekenissen en elementen ervan. Dit proefschrift biedt een raamwerk dat de identificatie en coördinatie van verschillende verantwoordelijkheden in de inherent onzekere O&I-omgevingen ondersteunt. De belangrijkste onderzoeksvraag van het proefschrift is: Hoe worden verschillende elementen van verantwoordelijkheid geïdentificeerd en uitgevoerd in O&I? Als resultaat zal dit proefschrift een meta-verantwoordelijkheidskaart presenteren: een hulpmiddel voor industriële O&I-teams en consortia om na te denken over hun verantwoordelijkheden, in situaties zoals het stellen van doelen, het oplossen van problemen, besluitvorming en interactie met belanghebbenden.

Hoofdstuk 1 schetst het maatschappelijke probleem dat aan dit werk ten grondslag ligt: de uitdagingen die onzekerheid van innovatie stelt bij pogingen om de resultaten en bredere maatschappelijke effecten ervan te sturen en te beheersen. De belangrijkste referentieliteratuur, die over verantwoord onderzoek en innovatie (RRI), wordt gepresenteerd, gevolgd door de introductie van de hoofdonderzoeksvraag en de algemene benadering van dit proefschrift.

Drie onderzoekspapers die antwoorden geven op de hoofdonderzoeksvraag worden gepresenteerd in de hoofdstukken 2-4. Hoofdstuk 2 introduceert een

verantwoordelijkheidskader dat het uitgebreide begrip verantwoordelijkheid onderverdeelt in vier elementen: zorgdragen, aansprakelijkheid, verantwoording en responsiviteit. Door een O&I-project in de opkomende sector van de bio-economie te bestuderen, wordt dit theoretisch geconstrueerde raamwerk verder ontwikkeld tot een metaverantwoordelijkheidskaart met praktische toepasbaarheid. De metaverantwoordelijkheidskaart plaatst verschillende naast elkaar bestaande (en soms tegenstrijdige) principes, verwachtingen en verplichtingen in overkoepelende terminologie – verantwoordelijkheid – en ondersteunt van daaruit hun afstemming in de O&I-settings.

Hoofdstuk 3 ontwikkelt de metaverantwoordelijkheidskaart benadering verder om toepasbaar te zijn in multi-actor O&I-netwerken. Bij de industriële O&I van vandaag zijn vaak meerdere industriële en academische deelnemers betrokken die als een consortium werken. Terwijl ze nieuwe technologieën en materialen ontwikkelen, geven deze netwerken ook industriële waardeketens opnieuw vorm. Door twee bio-economische casestudies te onderzoeken, identificeert hoofdstuk 3 eerst kritische redenen die de toewijzing van verantwoordelijkheden in opkomende biobased waardeketens bemoeilijken, met name als het gaat om ongunstige indirecte effecten. Vervolgens wordt de metaverantwoordelijkheidskaart verder verrijkt om de verdeling van verantwoordelijkheden tussen deelnemers en belanghebbenden van O&I te ondersteunen: onder industriële innovators, regelgevers en beleidsmakers, evenals vertegenwoordigers van het maatschappelijk middenveld zoals eindgebruikers.

Hoofdstuk 4 gaat dieper in op responsiviteit, een verantwoordelijkheidselement dat bijzonder bepalend lijkt voor O&I als een proactieve mentaliteit die het werken onder onzekerheid ondersteunt. Bij praktisch O&I-werk in de particuliere sector wordt het idee van responsiviteit, zoals gepresenteerd in RRI-literatuur, op veel manieren in twijfel getrokken. Met name het idee van "wederzijdse responsiviteit" tussen innovators en maatschappelijke belanghebbenden lijkt problematisch. Door de bestaande RRI-literatuur over responsiviteit te beoordelen, waaronder theoretische studies en drie industriële casestudies, stelt hoofdstuk 4 'creatieve benaderingen' voor om responsiviteit jegens maatschappelijke behoeften en belanghebbenden in te bedden in O&I.

In Hoofdstuk 5 worden de algemene conclusies gepresenteerd als antwoord op de hoofdonderzoeksvraag. Verantwoorde innovatie vereist verschillende naast elkaar bestaande strategieën om de onzekerheid van innovatie te beheersen. In de benadering van dit proefschrift worden deze strategieën gepresenteerd onder de vier

verantwoordelijkheidselementen zorg (waarden en normen als richtlijn), aansprakelijkheid (wettelijke/contractuele vereisten als richtlijn), verantwoording (evaluatie van effecten) en responsiviteit (al doende leren). Voor elk element wordt samengevat wat hun implementatie vereist van O&I-uitvoerders, en wie in de O&I-netwerken moeten deelnemen aan de implementatie ervan, opdat innovatie als verantwoordelijk wordt beschouwd. Vervolgens wordt de metaverantwoordelijkheidskaart benadering gepresenteerd in zijn definitieve vorm, inclusief begeleidende vragen die zijn ontworpen om een discussie op gang te brengen over de verantwoordelijkheidselementen die op het spel staan.

De gepresenteerde metaverantwoordelijkheidskaart is bedoeld om spanningen tussen de uiteenlopende verantwoordelijkheden die spelen O&I bespreekbaar te maken en daarmee beheersbaar. Hoewel deze benadering voor een groot deel is ontwikkeld in de bio-economische context, kan deze benadering ook interessant zijn voor andere industrieën die te maken hebben met maatschappelijke problemen die verband houden met b.v. ecologische duurzaamheid en ethische kwesties in waardeketens. De aanpak kan onder meer de afstemming van winstgerichte doelen met wereldwijde milieu-uitdagingen ondersteunen. Wanneer metaverantwoordelijkheid in een vroeg O&I-stadium wordt toegepast, kan het ook anticipatie op toekomstige verantwoordelijkheden ondersteunen en keuzesituaties die zich in latere O&I-stadia dichter bij commercialisering kunnen voordoen. Wanneer toegepast in O&I-omgevingen met meerdere actoren, adresseert meta-verantwoordelijkheid het risico van "verantwoordelijkheidsverdunning" tussen deelnemers aan de waardeketen. Ten slotte kan de systematische benadering van verantwoordelijkheid die in dit proefschrift is ontwikkeld, de theoretische degelijkheid en praktische relevantie van RRI als een benadering van innovatiebeleid en -management vergroten.

Chapter 1

General Introduction

"The more complex our technologies become, and the more embedded in the social and natural worlds, the more like unfathomable 'black boxes' they become – perhaps even to their creators. The more intimately they interact with nature – and with each other – the more 'autonomy' they have in creating unpredictable effects. Being ignorant of the future impacts of one's innovations may, therefore, become the norm rather than the exception."

(Grinbaum & Groves, 2013, p. 124)

Companies, as all institutions, have multiple responsibilities – duties, obligations and expectations – to fulfil in society. At the crux of corporate activity is the expectation of profitability, of creating value for the shareholders invested in the company. Companies are also expected to obey the law, to do business within limits of legal frameworks such as environmental legislation. Further, employers are responsible for ensuring safe and healthy working conditions for their employees. Already for decades, the private sector has also assumed social and morally binding responsibilities beyond economical obligations and minimal legal requirements. For instance, Corporate Social Responsibility (CSR) is a widely adopted approach in companies to address ethical norms, standards and expectations of consumers, societal stakeholders and the wider public (Schwartz & Carroll, 2003).

This doctoral thesis derives its motivation from the multifaceted character of responsibility, taking many forms that co-exist and at times also conflict. Responsibility is a big word, easily summoned but a tall order to accomplish. Conveying multiple meanings, a non-specific usage of the term is also prone to misinterpretations – intentional or not – and blurring of actual responsibilities. *Who*, *for what*, *to whom*, *in what sense* and *how* are useful words to accompany any demand for responsibility.

The context of this study is the private sector Research and Innovation (R&I), specifically R&I related to industrial manufacturing of future goods and materials. R&I is one of the main means for companies to secure their future viability, fulfil the company's strategical goals and vision of what it wants to be in future, and also, how it will impact the

society and natural environment. As a future-oriented activity R&I is steeped with uncertainty regarding its outcomes, overall success, and eventual impacts in society. This unpredictability creates dilemmas with regard to responsibility. For instance, how can R&I operators take responsibility for future impacts that are still unknown at the time of R&I? How far into future does their responsibility reach? Is it justifiable, in the first place, to consider them responsible for far-reaching, indirect societal impacts? Furthermore, how should such responsibility be distributed between developers (R&I), enablers (funders, regulators) and appliers (users) of the innovation?

This thesis builds on the idea that in order to address such questions, the broad notion of responsibility first needs to be opened up, to distinguish between its different meanings and elements. For theoretical point of departure, this thesis looks to the literature of Responsible Research and Innovation (RRI). As a *"meta-responsibility approach"* (Stahl, 2013), RRI could provide a framework for R&I projects to cope with their various responsibilities, in light of the persistent uncertainty. To be implementable in industry, such approach also needs to acknowledge existing structures, processes, codes and responsibilities in private sector (Chatfield, et al., 2017a).

RRI includes mechanisms to address the radical uncertainty of R&I. It supports *anticipation* of possible consequences of innovation in society and in natural environment, and encourages *reflexivity* in terms of keeping a critical eye on the goals and initial assumptions of innovation, and staying conscious of the limitedness of knowledge and control. Also, RRI promotes *inclusion* of stakeholders in order to enhance understanding about societal impacts and desirability of the innovation. Eventually, the R&I practitioners need to demonstrate *responsiveness* to the findings from all these inquiries: to make modifications to the properties and pathway of innovation towards improved societal impacts and acceptability. (Stilgoe, et al., 2013; Lubberink, et al., 2017)

While RRI has been prominent in the EU's research policies since 2010s, as an innovation management approach it remains largely unfamiliar and marginally adopted in industry (Dreyer, et al., 2017; Martinuzzi, et al., 2018). At the same time, many individual elements promoted in RRI are well familiar in the business context, and their value for successful innovation is widely acknowledged. There are many methods in use in corporate R&I today, through which questions of RRI can be asked – such as technology assessments and scenarios for *anticipation*, or, focus groups for *inclusion* (Stilgoe, et al., 2013). In the same vein; the building blocks of RRI typically exist under different names in innovation

management (Dreyer, et al., 2017). For instance, business model generation and risk analyses represent actions of *anticipation*, while Agile Project Management echoes with *responsiveness* (Ibid.).

There appears no shortage of tools and methods to advance RRI's goals. Instead, the private sector seems to lack a tailor-made approach for R&I to identify and then coordinate its responsibilities. When developed into a meta-responsibility approach (Stahl, 2013), RRI could provide this overview on responsibilities – and then function as a "manual" for choosing tools and methods to support fulfilling individual responsibilities. The current mainstream approaches in the private sector do not fully serve this task. While *CSR* has been widely applied in companies to address responsibilities in many of their operations, it has been adopted in R&I processes only to a limited extent (van de Poel, et al., 2017) – possibly because it fails to fully deal with unpredictable and unknown outcomes (Pellé & Reber, 2015). In a similar vein, there are established innovation management approaches with linkages to RRI's themes, such as *Sustainable Innovation* and *Social Innovation* aiming at reaching positive societal impacts with innovation (e.g. Lubberink et al. (2017)), or, *Open Innovation* (e.g. Long & Blok (2018)) that resonates with stakeholder inclusion. However, these approaches do not explicitly address coordination of responsibilities.

This doctoral thesis develops a meta-responsibility framework for R&I, and demonstrates its applicability in practical R&I contexts. The main research question of the thesis is: *How do different elements of responsibility become identified and carried out in R&I?* For answering this question, an inventory of responsibilities is required but alone insufficient. In daily work, R&I operators are coping with various duties and expectations, which not only need to be identified but also brought together and negotiated in decision making situations. Hence, understanding the interconnectedness of different aspects of responsibility – having dependences, conflicts and synergies – is required for responsible innovation. As outcome, this thesis will present a tool (a *"meta-responsibility map")* for R&I projects and consortia to support alignment of their responsibilities. The tool is designed to facilitate responsible innovation in situations like goal-setting, problem-solving and decision-making in R&I.

This Introductory chapter begins by presenting the societal problem addressed in this thesis: the different forms of uncertainty that make responsibility in R&I a challenging task to fulfil (Chapter 1.1). Next, the approach of Responsible Research and Innovation (RRI) will be presented, as an approach that includes mechanisms for managing with the

radical uncertainty characteristic to R&I. Chapter 1.2 will present the academic problem of this thesis, reviewing the development needs that RRI is facing in order to become a feasible innovation management approach. Namely, it will present the idea of developing RRI into a *meta-responsibility* approach to enable coordination and management of responsibilities in R&I. Chapter 1.3 will provide a short outlook on characteristics of the private sector context, which need to be taken into account when developing a responsibility framework for industrial R&I. Chapter 1.4 will summarize the research conducted within this doctoral thesis, which will be presented in full in the later chapters. Finally, Chapter 1.5 will provide a "reader's guide" – a visualized structure of this doctoral thesis.

1.1. Theoretical background: the vision of responsible innovation

Few would oppose the idea of innovations meeting societal needs and acceptability, nor is that idea new. Technological development has always been accompanied with optimism as well as concerns regarding its impacts in society. Modern history is abound with technological success stories that have enabled today's lifestyles and well-being – such as antibiotics, the Internet, fuel engines or nuclear power – but also brought about gradual deterioration of health and environment (antibiotic resistance, CO_2 emissions), accidents (car traffic, nuclear power), misuse (spread of misinformation in digital media), and dual use (nuclear weapons), to name a few. Risks related to novel technologies, some of which have remained speculative while others have realized with catastrophic extents, involve questions about how responsibility for consequences distribute between technology developers, enablers (e.g., funders) and adopters (users).

Over time, debates related to opportunities and risks of novel technologies have given rise to mechanisms of innovation governance. In line with Stilgoe et al. (2013) and Pellizzoni (2004), governance of innovations has evolved through frustrations regarding the limitedness of control. First, it became evident the latest in the 1950's–1960's that relying on the "technical fix" or on the market choice are far from being sufficient measures to control negative outcomes. High number of accidents, as well as escalation of longer-term impacts such as environmental pollution, lead to the introduction of risk regulation, basing on judicial responsibility (i.e. liability) obliging industries to comply with in order to maintain their license to operate. These were soon accompanied with voluntary schemes of self-regulation, such as the decades-old CSR, through which institutions seek justification

and social responsibility (accountability) to themselves, stakeholders and the public, by means of complying with standards, certifications and accreditations, for instance (Pellizzoni, 2004; Pellé & Reber, 2015).

However, it has become obvious that risk regulation does not suffice for governing technological innovations, whose impacts spill over predictable risks, expected benefits, intended usage, and simple cause–consequences. Largely, this is owing to the inherent uncertainty of innovation activity and the increasing complexity of novel technologies.

1.1.1. Uncertainty, complexity and limitedness of control

It is highly challenging to foresee impacts of innovation. As a future-oriented activity, R&I is steeped with uncertainty regarding its outcome, impacts and the overall success. On one hand, uncertainty stems from scarcity of knowledge, which van de Poel et al. (2017) call *epistemological uncertainty*. For instance: at a small-scale developmental stage, it is still much uncertain how a technology will eventually perform once it is introduced in society in full-scale. More knowledge is gained via research and other modes of investigation, but all uncertainty can hardly be resolved before the launch. On the other hand, *indeterminate uncertainty* derives from the huge number of options that are still open during R&I, such as product design and process configuration options (van de Poel, et al., 2017). This uncertainty of open causal chains is reduced only "by doing" – by choosing certain options and excluding others.

These uncertainties become reduced as the innovation proceeds and more knowledge is gained. Simultaneously however, the ability to make changes to the properties and pathways of the innovation, as response to the acquired knowledge, becomes reduced as well. This is the so-called *Collingridge dilemma* (Collingridge, 1980; Blok & Lemmens, 2015; van de Poel, et al., 2017). Lack of knowledge is a challenge especially at early stages of innovations (high epistemological uncertainty), while there would still be plenty of options to modify the innovation (high indeterminacy). At later stages, closer to maturity, the knowledge basis becomes more firm (reduced epistemological uncertainty), but the innovation is already "locked-in" to certain properties and configurations (reduced indeterminacy). At that point, making any considerable changes to those properties would imply remarkable costs and delay.

It is often highly challenging to trace actualized impacts back to their root causes and initiators. Besides limited knowledge, the complexity of interactions between innovation and the surrounding world brings about considerable unpredictability. As per Grinbaum and Groves (2013, p. 124), innovation is creative action that "point[s] forward, opening up the world the past has created and adding new entities to it that change the way it works". How a novel product, service or process impacts society and natural environment can be a complex chain of causes and consequences. Those are highly difficult to foresee, and once realized, to trace back to their initiators (van de Poel, et al., 2012). The more advanced the technologies are, then more "entangled" they become in their interaction with natural environment, society, and with each other (Grinbaum & Groves, 2013). As result of this complexity, the indirect and unintended impacts of human activity – such as those on climate, food security or biodiversity – often seem to spin out from collective action, rather than being attributable to single actors, which is sometimes referred to as the "Problem of many hands" (Thompson, 1980). Van de Poel (2012) exemplifies global warming as a typical many hands' problem: a very complex phenomenon where a large number of individuals is causally involved, but in which the role of individuals in isolation is rather small. In such situations, it is usually very difficult to pinpoint individual responsibility (Ibid.).

What is a "good impact"? Innovations not only invoke concerns about risks, but also more profound deliberation on their purpose ("why is it needed?"), as well as on their justification ("what is a 'good' outcome of innovation in the end?"). Especially highly novel and disruptive technologies can "rob our moral routines" of their self-evidence (Swierstra & Rip, 2007) and turn them into topics of deliberation and sometimes dispute. Asveld and Stemerding (2017) theorize that *ambiguous uncertainty* is a particular type of uncertainty that arises from diverging perspectives regarding what is good and valued in innovation. For instance, broadly agreed norms such as "sustainability" or "safety" may, at a closer look, convey various and sometimes conflicting expectations and interpretations. Asveld (2016) provides an example in the context of biofuels development, the impacts of which have been heavily debated. The acceptability of biofuel crop cultivation has been questioned from the viewpoint of food security (i.e. "food-for-fuel" arguments), but also endorsed as a means of poverty reduction (providing extra income for farmers). Often deriving from differing value and cultural bases, such viewpoints can be difficult to prioritize or "prove wrong" against one another (Asveld & Stemerding, 2017). Moreover, understandings about what is acceptable and worth aspiring in society can change over

time, with changes in consumer preferences or societal values, for instance (van de Poel, et al., 2017).

1.1.2. From governance of risk to governance of innovation

From this radical uncertainty follows that management of innovations cannot be reduced to risk regulation. The so-called negative or "backward-looking" responsibilities promoted in risk regulation, such as legal liability, operate based on "holding someone responsible" for the impacts (Grinbaum & Groves, 2013). It appears often unfeasible and also unjust to hold individual R&I operators responsible for wider societal impacts resulting from far-reaching causal chains. In line with van de Poel and Sand (2018), *holding responsible* requires that there is a demonstratable causal connection between the agent and the object (i.e., a manageable level of complexity), and that the agent has capacity to deliberate impacts of actions (reasonably low epistemological uncertainty and indeterminacy). Also, it should be fairly clear that the impacts of innovation are societally desirable (low ambiguity), so that the agent can judge in due time whether their intention is right or wrong (van de Poel & Sand, 2018; Asveld & Stemerding, 2017). These requirements rarely coincide fully in innovation. On what basis, then, can R&I operators assume responsibility for those uncertain and broader societal outcomes? Seeking answers to this question marks another shift in the governance of innovations, gradually gaining foothold since ca. 1980s.

The term "responsibility", by its narrowest literal definition, derives from the Latin word *respondere*: to answer (Timmermans, et al., 2017; Pellizzoni, 2004; French, 1979). While radical uncertainty of innovation makes this answerability as *holding responsible* questionable, it does not impede actors from *taking responsibility* nevertheless (Grinbaum & Groves, 2013). Besides answerability, responsibility has more positive, "forward-looking" and proactive meanings. As Pellé and Reber (2015, p. 113) formulate: "we are driven not only by the fear of sanctions, but also by our wish to ensure certain course of events will or will not happen". Despite uncertainties, innovators can actively work towards reaching a desired state-of-affairs – even when it would be unfair to externally hold them responsible for it (van de Poel & Sand, 2018). In responsibility literature, this mindset has been labeled as an "obligation", "care", "virtue", "moral responsibility" or a "collective stewardship" to see that the certain desired state-of-affairs will likely occur (e.g. Pellé & Reber (2015), Pellizzoni (2004), Stilgoe et al. (2013), van de Poel & Sand (2018)). Moreover, in order to weather the radical uncertainty of R&I, the forward-looking conduct should acknowledge

the insufficiency of knowledge, be proactive at gaining new knowledge, and be ready to adjust courses of action based on the emerging knowledge. In responsibility literature, that mindset is referred to as “adaptiveness”, “resilience”, or “responsiveness”, among others (e.g. Pellizzoni (2004), Lee & Petts (2013), Stilgoe et al. (2013), Asveld & Stemerding (2017)).

1.1.3. Emergence of Responsible Research and Innovation (RRI)

In literature on innovation governance, several approaches have ensued that target to include broader societal issues into the governance of innovation, by mobilizing forward-looking aspects of responsibility. These include (but are not limited to) bioethics and Technology Assessment (TA) emerging before the 1990s, and Ethical, Legal and Social Aspects/Impacts (ELSA/ELSI) starting from 1990s (Zwart, et al., 2014; Lubberink, et al., 2017). The approach of *Responsible Research and Innovation (RRI)* is a recent continuation of this history. As an *academic literature* field, RRI borrows many principles, processes and tools from its predecessors. RRI is also a *political formulation*, emerged in early 2010s when elements from these previous traditions were gathered under the research policy framework of the European Commission (EC) (Zwart, et al., 2014). In this position, RRI became a cross-cutting theme also in the EC’s research funding programs such as Horizon2020 (European Commission, 2012).

According to the initial formulation of RRI, responsible innovation is an ongoing process of aligning R&I to the values, needs and expectations of society (Rome Declaration, 2014). The influential framework by Stilgoe et al. (2013) suggests a set of elements, representing society’s typical concerns and interests in innovation, that should be included in the R&I process for it to be considered as responsible. *Anticipation* of outcomes and impacts requires systematic thinking about known, likely, plausible and possible implications of innovation, envisioning “desirable futures” reachable with innovation, and then organizing resources to meet those. *Reflexivity* involves self-scrutiny of one’s activities, commitments and assumptions, being aware of limitedness of knowledge and the fact that one’s goals, values and interpretations may not be universally held. *Responsiveness* is required to feed findings of anticipation and reflexivity into decision making and actions. It is about having and using the capacity to adjust the properties and pathways of innovation (e.g. configurations, product design) so that it becomes societally more embedded. (Lubberink, et al., 2017; Stilgoe, et al., 2013).

Furthermore, the approach of RRI emphasizes the importance of stakeholder *inclusion*. Von Schomberg (2013, p. 19) provides a much-quoted definition of RRI highlighting stakeholder interaction:

"Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)."

From responsibility viewpoint, the above definition borrows from the understanding of responsibility as a forward-looking "collective stewardship" of taking care of future by innovation (van de Poel & Sand, 2018). Given that unpredictable impacts have a character of being "problem of many hands", also the responsibility for addressing those has a shared character (Stilgoe, et al., 2013; van de Poel, et al., 2012). Von Schomberg (2013) calls this a "co-responsibility" of innovators and stakeholders for the societal outcomes of innovation.

In total, RRI's procedural approach to responsible innovation accommodates radical uncertainty and explicitly takes it into account in innovation governance. In particular, the *responsive* mindset appears pivotal for the success of R&I, being a future-looking element of responsibility that is simultaneously sensitive to uncertainty. Responsiveness, while acknowledging the uncertain open-ended character of innovation, takes innovation forward with readiness to adjust course of innovation as new knowledge is gradually gained and learnt (Pellizzoni, 2004).

1.1.4. RRI's limitations signal broader development needs in governance of innovation

RRI, however, has considerable limitations that hamper its theoretical integrity as well as practical applicability. The Section 1.2 introduces a major *conceptual limitation*: RRI tends to focus on certain responsibility elements while overlooking others, which boils down to a lack of proper framework for RRI's core concept – responsibility. Section 1.3. summarizes *contextual limitations* that RRI faces in the particular context of private sector R&I, giving insights for why RRI has remains marginally adopted in industry.

These limitations, while arising from the context of RRI, also indicate requirements and development needs for innovation governance in general. This doctoral thesis will provide an answer to its research question by developing a framework that facilitates inventory and management of responsibilities in industrial R&I projects. In light of the earlier developments of innovation governance, this framework needs to:

1. be indiscriminatory, in the sense that it acknowledges various elements and interpretations of responsibility: backward- as well as forward-looking, legal-contractual and moral, existing and emerging responsibilities, and role-specific responsibilities as well as shared normative principles.
2. reach beyond promoting individual aspects of responsibility, into the level of coordination and management of responsibilities in R&I. The framework should facilitate explorations on how elements of responsibility are brought together and negotiated in R&I work and decision making.
3. acknowledge characteristics of private sector and industrial R&I, so as to enable responsibility management in this context.

1.2. Need for a framework for responsibility in R&I

As its name suggests, the approach of *Responsible* Research and Innovation invokes the concept of responsibility for addressing relationship between R&I and society (Timmermans, et al., 2017). Against this backdrop, the concept of responsibility in RRI remains surprisingly underdeveloped. Pellé and Reber noted in (2015) that RRI lacks a proper investigation of its core term: The very definition of responsibility (of whom, to whom, where, when, in what way) had never been considered systematically. Still in (2017), Timmermans et al. observed a nonexistence of any theoretical account of responsibility. Dreyer et al. (2017) remarked that a clarified concept for responsibility is required for RRI to make an impact in industry.

The vagueness surrounding the concept of responsibility runs risk of several implications. One is that RRI as an innovation governance approach fails to demonstrate its added value in comparison to other approaches with similar elements. Timmermans et al. (2017) emphasize that RRI needs to be very specific about the linkage between responsibility and R&I, in order to communicate its novelty and uniqueness. Among others, this is to distinguish RRI from *CSR* whose focus is on responsibility but not specifically on R&I context, from *Sustainable Innovation* and *Social Innovation* that focus on R&I but do not involve an explicit mechanism for addressing uncertainty, and RRI's direct predecessors

such as TA and ELSA that address uncertainty but not under the label of responsibility specifically (Pellé & Reber, 2015; Lubberink, et al., 2017).

Similarly, a lack of responsibility framework can lead to insensitivity to pre-existing duties and responsibilities, implying that RRI as an innovation governance approach fails in communicating its relevance to R&I practitioners. Such situation can arise when new obligations are prompted without taking into account the existing ones. R&I projects and personnel are already laden with multiple responsibilities, such as those related to funding conditions and fulfilling short-term targets, and new obligations imply increasing workload. Any "novel" demands, such as those related to broader societal responsibility, need to be framed clearly in terms of their purpose, scope and benefits, with extant responsibilities taken into account (van de Poel, et al., 2017). So far, a large proportion of RRI studies focuses on promoting individual instances of responsibility, especially moral and wider societal responsibilities, thus selectively highlighting certain elements while others remain less addressed and thus somewhat obscured (Timmermans, et al., 2017).

Besides being dysfunctional, an unspecific concept of responsibility may actually backfire by further diffusing responsibilities in R&I. Blok & Lemmens (2015) and Zwart et al. (2014) call attention to the risk that promoting "co-responsibility" among innovators and stakeholders may lead to blurring of roles, tasks and accountabilities. Such case might arise, for instance, if the distinction between forward-looking and backward-looking responsibilities is not made clear. Rather than clarify, this might further complicate the Problem of many hands (van de Poel, et al., 2012). Also vice versa: promoting the backward-looking sanctioning of *holding responsible* in contexts of high causal complexity can be detrimental by discouraging innovators from *taking responsibility* in the forward-looking sense (van de Poel & Sand, 2018).

1.2.1. RRI as "meta-responsibility" to provide framework for responsibility

Developing a framework for responsibility in R&I, this thesis builds on the idea by Stahl (2013) that RRI can best enhance the governance of innovations as a higher-level responsibility, or, *meta-responsibility* that:

> *"aims to shape, maintain, develop, coordinate and align existing and novel research and innovation-related processes, actors and responsibilities with a view to ensuring desirable and acceptable outcomes" (Stahl, 2013, p. 712).*

In line with this formulation, the novelty of RRI is less in adding new elements of responsibility, but rather in shifting above individual responsibilities and providing a "bird's eye view" (Stahl, et al., 2017) on various responsibilities, duties, expectations and obligations that co-exist in R&I. Meta-responsibility stands as an approach to coordinate and manage these responsibilities in order to reach viable and societally acceptable R&I outcomes. This scope encompasses pre-existing as well as emerging, forward-looking and backward-looking, risk- as well as opportunity-driven, and occupational as well as moral responsibilities. Stahl (2013) and later Timmermans et al. (2017) suggested that this synthesis outlook marks another shift in governance of innovation, which is illustrated in Fig. 1.1.

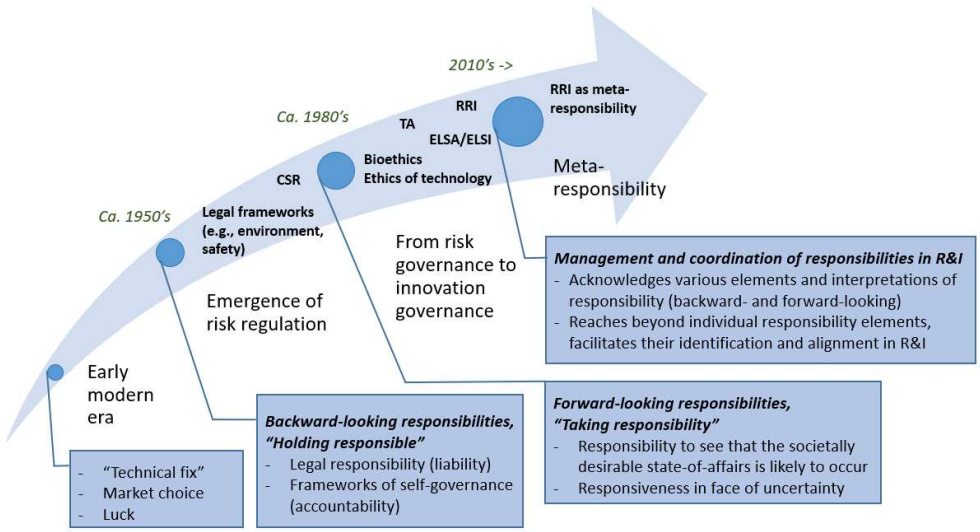

Figure 1.1. Development of innovation governance.

Since the idea of RRI as meta-responsibility was introduced by Stahl (2013), a number of studies in the RRI field have further built on it – all in the context of industrial R&I. Outside the research articles constituting this Thesis, and by March of 2022, those studies include: Chatfield et al. (2017a) and (2017b), Timmermans et al. (2017), Stahl et al. (2017), Ceicyte & Petraite (2018) and Ceicyte et al. (2021). This previous literature contributes to this Thesis as key background literature. Chatfield et al. (2017a) and (2017b), and Stahl et al. (2017) have provided a meta-responsibility outlook on decision making in individual R&I projects and companies, to evaluate to which extent the goals of RRI have been operationalized. Timmermans et al. (2017), Ceicyte & Petraite (2018), and Ceicyte et

al. (2021) apply meta-responsibility in the context of multi-actor R&I networks, by exploring distribution of responsibilities in R&I consortia.

What distinguishes this study from the earlier work on meta-responsibility is the emphasis on interrelatedness and dynamics between different understandings of responsibility: how different responsibilities (duties, expectations, obligations) related to the R&I process and outcomes co-exist and become negotiated in R&I projects.

1.3. Meta-responsibility in the context of industrial R&I

This sub-chapter recapitulates key limitations that have been reported in RRI literature to exist between RRI's scope and ideals, and the reality of industrial R&I. As hypothesis, this thesis suggests that these limitations are to a large extent surmountable with a meta-responsibility approach.

Focus on research, rather than innovation. Originally a research policy and academic approach, RRI has focused more on the *research* than the on *innovation* during its early years (Dreyer, et al., 2017; Blok & Lemmens, 2015; Lubberink, et al., 2017). Dreyer et al. (2017) emphasize that research and innovation are two very different processes. On one hand, *research* involves generation of knowledge – "using money to generate knowledge" – by basic research that often (but not exclusively) takes place in academia and research institutions. *Innovation* is the process of translating an idea into value and benefits for which customers will pay – "using knowledge to generate money" – that often (but not exclusively) takes place in the private sector (Dreyer, et al., 2017)[1]. With its initial focus on publicly funded research, RRI has offered limited perspectives on what responsibility constitutes and requires in privately funded settings – especially at later R&I stages close to commercialization. For instance, it has been limitedly addressed how broader societal goals sit together with the companies' core responsibility for profit generation. *As hypothesis, as meta-responsibility RRI can simultaneously address questions related to "research" (e.g. addressing epistemological uncertainty) as well as to "innovation" (e.g. co-existence of societal and commercial goals).*

[1] Some scholars make this distinction also by terminology: "Responsible Innovation" (RI) is sometimes used when referring to R&I in commercial settings, to distinguish from basic research (RRI). In this doctoral thesis, the label of RRI is used for both contexts.

Principles of inclusion sit uneasy with the asymmetry of knowledge and power. By its initial formulation, RRI is defined as "a transparent, interactive process by which societal actors become mutually responsive to each other" (von Schomberg, 2013, p. 19). Furthermore:

> *"technical innovators become responsive to societal needs and societal actors become co-responsible for the innovation process by a constructive input in terms of defining societal desirable products" (von Schomberg, 2013, p. 21).*

R&I is among the main means of how companies secure their existence in future (Blok & Lemmens, 2015). With R&I, companies seek to recognize and valorise opportunities before others in order to gain competitive advantage. This implies that knowledge and power asymmetries between the company, its competitors and other stakeholders are actively pursued (Blok & Lemmens, 2015; Dreyer, et al., 2017; Martinuzzi, et al., 2018). Blok and Lemmens (2015) have discussed implications of this situation on the applicability of RRI's principles in industrial contexts. Transparency, mutual responsiveness and co-responsibility between innovators and stakeholders appears naive and risky from business perspective (Ibid.). At the same time however, stakeholder inclusion and knowledge sharing bring clear advantages, in terms of identifying needs and increasing the likelihood of innovation to meet the demands and acceptability once brought to markets (van de Poel, et al., 2017). This suggests that balancing between exclusion and openness demands careful consideration in industrial R&I. *With meta-responsibility, both competitiveness and societal acceptability become perceived as manifestations of responsibility (e.g., for shareowners, further to society). This outlook can support attempts to find balance between these (somewhat contradictory) goals, and identify strategies for how one goal can be met while not risking the other.*

Responsibilities are highly networked (and easily diffused) in industrial value chains. Today's industrial production typically involves a large number of manufactures, so that final products become formulated via several intermediary stages, passing from one manufacturer to another. Correspondingly, R&I activities are often arranged and funded as part of wider research consortia, involving several participants from industry as well as from research institutions. While developing novel products and processes, these collaborations are also shaping future value chains of industrial manufacturing. From RRI, the multi-actor environment requires a networked theory of responsibility: responsibilities are in many ways interrelated, formulating networks of governance between the actors

(Timmermans, et al., 2017; Ceicyte & Petraite, 2018). *Meta-responsibility, when enabling inventory of R&I participants, stakeholders, and their responsibilities (who, to whom, for what), can support allocation of responsibilities in the emerging value chains.* In particular, an approach that supports coordination of responsibilities can contribute in mitigating the "Problem of many hands" in value chains.

1.4. Research approach

This thesis consists of three research papers providing answers to the main research question: *How do different elements of responsibility become identified and carried out in R&I?*

The first study, presented in **Chapter 2,** develops a meta-responsibility framework to support decision-making in industrial R&I projects, and then assesses its applicability in a practical R&I context. The sub-research question of Chapter 2 is: *How do (theoretically formulated) elements of responsibility become operationalized in practical R&I, and how can this outlook support responsible innovation?*

To answer this question, Chapter 2 takes as a starting point a responsibility framework introduced by Pellizzoni in (2004), itemizing responsibility into elements of *care, liability, accountability* and *responsiveness*. Upon reviewing extant RRI literature on meta-responsibility, this framework is developed in Chapter 2 to be more applicable in the context of high uncertainty of R&I. The practical applicability and validity of this theoretical framework is then explored by case-studying an ongoing, early-phase R&I project in the emerging sector of bioeconomy (i.e. manufacturing industry utilizing bio-based raw materials). Drawing on empirical data from semi-structured interviews conducted among the case project participants, followed by qualitative analysis, it was explored how different responsibility elements became identifiable in practical R&I situations. Based on the findings, the theoretical meta-responsibility framework is developed into a "meta-responsibility map" with practical relevance. The meta-responsibility map brings various co-existing (and sometimes contradicting) principles, expectations and obligations of R&I under a common terminology – responsibility – and from thereon supports their alignment in R&I settings.

Chapter 3 takes the responsibility framework developed in Chapter 2 into the context of multi-actor R&I networks, to explore how different elements of responsibility

become allocated amongst participants of emerging bio-based value chains. This means R&I consortia of bio-feedstock converters, industrial manufacturers and consumer brand owners, collaborating to develop novel bio-based products and production processes. The research question of Chapter 3 is: *How to apply the vision of responsibility in emerging value chains?* This question is posed against the background that today's industrial value chains are often lengthy and decentralized (geographically, institutionally), which can worsen the "Problem of many hands" (van de Poel, et al., 2012) in the sense that negative impacts of production remain widely unaddressed.

Chapter 3 further develops the meta-responsibility mapping approach, to become applicable in multi-actor R&I networks (in addition to individual R&I projects). This is done by linking the responsibility framework developed in Chapter 2 with an inventory of actors and their roles, to be able to explore how the elements of responsibility are taken forward in relations between these actors. Two empirical cases are explored: the bioeconomic case-study initially presented in Chapter 2, and another case in the sector of bio-circular economy (Kallergi & Asveld, 2021). As result, the "meta-responsibility map" is further enriched with elements facilitating allocation of responsibilities between R&I participants: among industrial innovators, regulators and policymakers, as well as civil society representatives.

Chapter 4 delves deeper into the responsibility element of *responsiveness*, in light of its high relevance in the R&I context as a proactive yet uncertainty-sensitive element. In practical R&I work in the private sector, the ideal of responsiveness, as it is presented in RRI, is challenged in many ways. In particular, the idea of *mutual responsiveness* between innovators and wider stakeholders (initially von Schomberg, (2013)) appears problematic. The research question is: *How to operationalize responsiveness R&I, given the limitations of mutual responsiveness identified in practical R&I contexts?*

To provide answers to its question, Chapter 4 reviews extant RRI literature on responsiveness, including theoretical studies as well as three industrial case studies (one on ICT, two on food innovations). As result, the Chapter 4 presents "creative approaches" for R&I to become responsive to societal needs, in light of the limitations related to implementation of mutual responsiveness in practice. Although this study chronologically took place before those presented in Chapters 2 and 3, it is presented last. This is for the sake of presenting the wider context of responsibility framework before focusing on one of its elements. It needs to be noted, however, that the meta-responsibility framework was

not yet developed at the time of the Chapter 4 study. As it happened, the need for a responsibility framework was one of the observations followed from this study.

Finally, synthesis based on the studies is presented in **Chapter 5.**

1.5. A reader's guide

Figure 1.2 visualizes the outline and scope of the thesis per chapter.

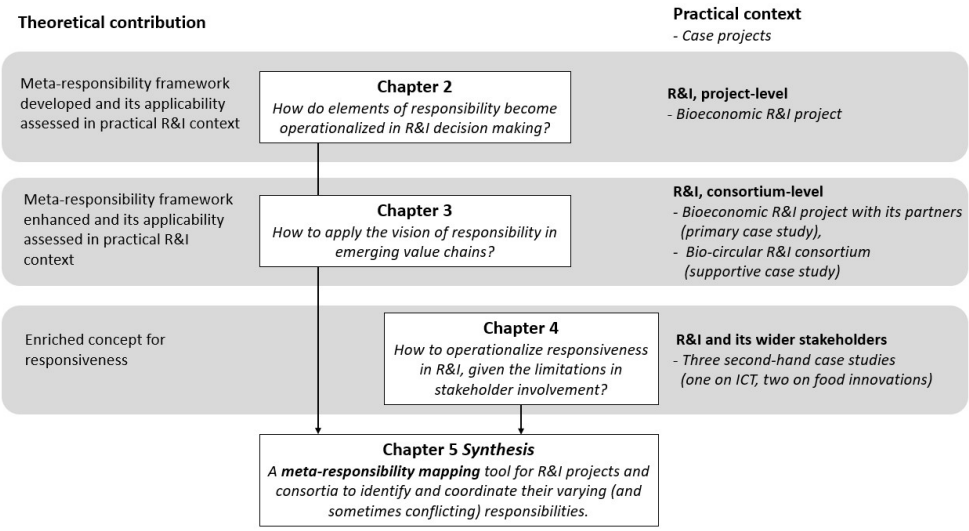

Figure 1.2. Scheme of the thesis outline and scope of the different chapters, with regard to theoretical contribution (left), research question (centre) and practical context (left).

References

Asveld, L., 2016. The need for governance by experimentation: The case of biofuels. *Science and engineering ethics,* 22(3), pp. 815-830.

Asveld, L. & Stemerding, D., 2017. Social learning in the bioeconomy: The Ecover case. In: *New perspectives on technology in society: Experimentation beyond the laboratory.* s.l.:Routledge, pp. 103-124.

Blok, V. & Lemmens, P. (2015). The emerging concept of responsible innovation. Three reasons why it is questionable and calls for a radical transformation of the concept of innovation. In B.J. Koops, I. Osterlaken, H. Romijn, T. Swierstra & J. van den Hoven (eds.), *Responsible Innovation 2: Concepts, Approaches, and Applications*, (pp. 19-35). Springer, Cham, Switzerland.

Ceicyte, J. & Petraite, M., 2018. Networked responsibility approach for responsible innovation: Perspective of the firm. *Sustainability,* 10(6), p. 1720.

Ceicyte, J., Petraite, M., Blok, V. & Yaghmaei, E., 2021. Responsible innovation in industry: The role of firm's multi-stakeholder network. In: E. Koukios & A. Sacio-Szymanska, eds. *Bio# Futures.* Cham: Springer, pp. 581-603.

Chatfield, K. et al., 2017b. An investigation into risk perception in the ICT industry as a core component of responsible research and innovation. *Sustainability,* 9(8), p. 1424.

Chatfield, K., Iatridis, K., Stahl, B. & Paspallis, N., 2017a. Innovating responsibly in ICT for ageing: Drivers, obstacles and implementation. *Sustainability,* 9(6).

Collingridge, D., 1980. *The Social Control of Technology.* London: Frances Pinter.

Dreyer, M. et al., 2017. Responsible innovation: A complementary view from industry with proposals for bridging different perspectives. *Sustainability,* 9(10).

European Commission, 2012. *Responsible research & innovation.* [Online] Available at: https://wayback.archive-it.org/12090/20220124160515/https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation [Accessed 31 March 2022].

French, P. A., 1979. The corporation as a moral person. *American Philosophical Quarterly,* 14(3), pp. 349-379.

Grinbaum, A. & Groves, C., 2013. What is "responsible" about responsible innovation? Understanding the ethical issues. In: R. Owen., J.Bessant & M. Heintz, eds. *Responsible innovation: Managing the responsible emergence of science and innovation in society.* London: Wiley, pp. 119-142.

Kallergi, A. & Asveld, L., 2021. *Biocomposite: Safe-by-design for the circular econonomy*. Available at: https://www.researchgate.net/publication/356917394_Biocomposite_Safe-by-Design_for_the_circular_economy [Accessed on 22 March 2022].

Lee, R. G. & Petts, J., 2013. Adaptive governance for responsible innovation. In: R. Owen, J. Bessant & M. Heintz, eds. *Responsible Innovation: Managing the responsible emergence of science and innovation in society.* Chichester: John Wiley & Sons, pp. 143-164.

Long, T. B. & Blok, V., 2018. Integrating the management of socio-ethical factors into industry innovation: towards a concept of Open Innovation 2.0. *International Food and Agribusiness Management Review,* 21(4), pp. 463-486.

Lubberink, R., Blok , V., van Ophem, J. & Omta, O., 2017. Lessons for Responsible Innovations in the Business Context: A Systematic Literature Review of Responsible, Social and Sustainable Innovation practices. *Sustainability,* 9(721).

Martinuzzi, A. et al., 2018. Responsible research and innovation in industry - Challenges, insights and perspectives. *Sustainability,* 10(3), p. 702.

Pellé, S. & Reber, B., 2015. Responsible innovation in the light of moral responsibility. *Journal on Chain and Network Science,* 15(2), pp. 107-117.

Pellizzoni, L., 2004. Responsibility and environmental governance. *Environmental politics,* 13(3), pp. 541-565.

Rome Declaration on Responsible Research and Innovation in Europe (2014). Available at: https://digital-strategy.ec.europa.eu/en/library [Accessed on 22 March 2022].

Schwartz, M. S. & Carroll, A. B., 2003. Corporate social responsbility: A three-domain approach. *Business ethics quarterly,* pp. 503-530.

Stahl, B. C., 2013. Responsible research and innovation: The role of privacy in an emerging framework. *Science and Public Policy,* 40(6), pp. 708-716.

Stahl, B. et al., 2017. The Responsible Reesarch and Innovation (RRI) maturity model: Linking theory and practice. *Sustainability,* 9(6), p. 1036.

Stilgoe, J., Owen, R. & MacNaghten, P., 2013. Developing a framework for responsible innovation. *Research Policy,* 42(9), pp. 1568-1580.

Swierstra, T. & Rip, A., 2007. Nano-ethics as NEST-ethics: patterns of moral argumentation about new and emerging science and technology. *Nanoethics,* 1(1), pp. 3-20.

Thompson, D. F., 1980. Moral responsibility and public officials: The problem of many hands. *Americal Political Science Review,* 74(4), pp. 905-916.

Timmermans, J., Yaghmaei, E., Stahl, B. C. & Brem, A., 2017. Research and innovation processes revisited : networked responsibility in industry. *Sustainability Accounting, Management and Policy Journal,* 8(3), pp. 307-334.

van de Poel, I. et al., 2017. Company strategies for responsible research and innovation (RRI): A conceptual model. *Sustainability,* 9(11), p. 2045.

van de Poel, I. et al., 2012. The Problem of Many Hands: Climate Change as an Example. *Science and Engineering Ethics,* 18(1), pp. 49-67.

van de Poel, I. & Sand, M., 2018. Varieties of responsibility: two problems of responsible innovation. *Synthese,* pp. 1-19.

Von Schomberg, R., 2013. A vision of responsible research and innovation. In: *Responsible Innovation.* London: Wiley, pp. 51-74.

Zwart, H., Landeweerd, L. & van Rooij, A., 2014. Adapt or perish? Assessing the recent shift in the European research funding arena from 'ELSA' to 'RRI'. *Life Sciences, Society and Policy,* 10(1), pp. 1-19.

Chapter 2

Meta-responsibility in corporate research and innovation: A bioeconomic case study

This chapter has been published as:

Sonck, M., Asveld, L., Osseweijer, P., 2020. Meta-responsibility in corporate research and innovation: A bioeconomic case study. *Sustainability* 12(1), 38.

2.1 Introduction

Companies, like all institutions, wield various responsibilities in society. In addition to economic obligations to shareowners and legal compliances, during the past decades, companies have assumed social and morally binding responsibilities beyond what is legally required of them [1]. With the escalation of global problems such as climate change and food insecurity, companies are increasingly seen to hold a key position in finding and developing solutions for societal challenges [2]. Considering this co-existence of different scopes and understandings of what corporate responsibility entails, any demand for introducing new responsibilities needs to be framed clearly with pre-existing responsibilities taken into account.

In recent years, a new call for responsibility has been added to those already existing, focusing on research and innovation (R&I) as a specific and relevant part of corporate activities. The literature of Responsible Research and Innovation (RRI, or RI) sets out to promote a wider responsibility in the context of R&I management and activities, with the aim of enhancing the "societal embeddedness" of innovations. According to RRI's dominant idea, by Owen et al. [3], R&I should anticipate and reflect on the impacts of an innovation in society, and innovators should be responsive by adjusting the shape (e.g., design) and direction of the innovation according to these considerations. This is a reasonable call, firstly considering that R&I units and teams play a key role in implementing the strategic goals of what a company aspires to be in the future—and thus how the company will impact the surrounding society and natural environment. Secondly, R&I is on the frontlines in observing and tackling uncertainties and unexpected turns that inherently accompany future-oriented activities.

Many activities endorsed in RRI are already mainstream in companies—such as stakeholder dialogue and risk assessments—and their value for successful innovation is widely acknowledged [2]. However, RRI as an integral, systematic approach remains unfamiliar (and unimplemented) in corporate R&I. As remarked by van de Poel and Sand [4], implementing RRI would attribute a range of new responsibilities into the daily work routine of R&I teams. As with any new approach, alleged benefits are carefully weighed against the workload added to existing duties and obligations. To convincingly communicate its added value and to spark any institutional change, the approach of Responsible Research and Innovation needs to be very specific in terms of what kind of

responsibility it exactly demands from R&I managers and personnel and how novel responsibilities align with existing ones.

In a similar vein, a few studies remark that RRI's practical relevance remains fundamentally hampered as long as it remains unspecific about the core concept of responsibility [5–7]. This largely boils down to the absence of a systematic framework that would provide an inventory of different responsibilities within R&I. For instance, while RRI is portrayed as a promoter of "wider" societal and moral responsibility, no framework exists that would translate this demand into a common language with R&I's extant responsibilities: economic, legal, contractual, as well as moral. Shortcutting without duly considering existing responsibilities is not only unsuccessful but also potentially detrimental when resulting in unclear role setting and dissolved responsibility [1,8].

In response, it has been proposed that RRI should be developed into a meta-responsibility approach, providing a systematic mapping of both existing and novel responsibilities that R&I functions hold in society [7,9–11]. This airplane view can reveal gaps, dependencies, and conflicts among current and emerging demands and expectations faced by corporate R&I. Furthermore, meta-responsibility would provide a foundation for introducing and aligning novel responsibilities, e.g., for meeting particular societal goals and for formulating practical recommendations for R&I personnel for their implementation [7].

Taking forward this approach, the paper at hand develops a model for meta-responsibility and demonstrates its applicability in practical R&I. By means of case study, we systematically explore responsibilities in a corporate R&I project, with the following research question: How do (theoretically formulated) elements of responsibility become operationalised in practical R&I, and how can this outlook support responsible innovation? For theoretical basis, Section 2.2 introduces the framework by Pellizzoni [12] outlining the four elements responsibility: care, liability, accountability, and responsiveness, and further, suggests an adaptation to this framework in order to render it more attentive to R&I as a highly uncertain future-oriented setting. Section 2.3 presents the empirical research material and methods, featuring a corporate R&I project in the bioeconomic sector (i.e., a manufacturing industry utilising bio-based raw materials). Bringing together theory and practice, Section 2.4 presents a meta-responsibility map and discusses its relevance for

facilitating responsible innovation in corporate R&I. Finally, the conclusions and limitations of the study are presented in Section 2.5.

2.2. Theoretical approach: unfolding responsibility in research and innovation

The present paper builds on an assembly of RRI studies calling for a more explicit and systematic account of the term responsibility, to support responsible innovation. As a point of departure, we look to the work of Stahl [10] proposing that RRI, in itself, should become such a framework. This implies that RRI should be reconceptualised into a meta-responsibility, to "shape, maintain, develop, coordinate and align existing and novel research and innovation-related processes, actors and responsibilities with a view to ensuring desirable and acceptable research outcomes" [10] (p. 708). Chatfield and colleagues [9] were the first to suggest utilising meta-responsibility in the private sector context as a means to enable RRI, since "fundamentally, for RRI to be adopted in industry, it must be implementable within existing organisations and aligned with their existing processes, codes and responsibilities" (p. 17).

Timmermans et al. [7] were the first to apply meta-responsibility for inventorying responsibilities in an industrial R&I case study. The authors modelled networks of allocated responsibilities in two industrial R&I cases, between subjects (i.e., those who are responsible), objects (what the subjects are responsible for), norms (criteria to act responsibly), and authorities (overseeing responsibilities and attributing sanctions). The study surfaced multiple responsibility relationships between these entities, among which certain aspects of RRI were also identifiable, such as anticipation and stakeholder engagement. The authors voiced a need to develop further methodologies for mapping responsibilities, and to explore these in light of R&I practices across different industries and types of organisation. Another mode of applying meta-responsibility is provided by Stahl et al. [11], as a "bird's eye view" to assess the extent to which RRI's principles are realised in the purposes (i.e., motivations), processes (activities undertaken), and products (outcomes) of R&I. The authors propose a five-stage RRI maturity model for organisations and demonstrate its validity with empirical insights from three industrial R&I cases.

Adding to the above literature, we remark that in order to devise meta-responsibility in innovation projects, one needs to define responsibility in a way that is

attentive to the particularities of the R&I context: namely, the persistent uncertainty that characterises innovation as a future-oriented activity. Here, we take as a point of reference the work by van de Poel and Sand on attributing responsibilities to innovators [4] and by Pellé and Reber on moral responsibilities in supply chains and innovation networks [6]. These RRI studies, although not referencing meta-responsibility by name, inventory different meanings of responsibility in R&I contexts, and in this sense implement meta-responsibility. In particular, both studies broach the question of how to conceptualise and eventually undertake responsibility during an R&I process, given the uncertainty about its outcomes and impacts.

2.2.1. Defining responsibility in an R&I setting

As a framework for defining responsibility, this paper applies the account by Pellizzoni [12], who in the context of environmental governance itemised the concept of responsibility into four elements—care, liability, accountability, and responsiveness. This framework was originally introduced into RRI by Owen et al. [3] already in 2013, but has remained limitedly applied, apart from the notable adoption of responsiveness as one of RRI's key elements. A more systematic revisit of Pellizzoni's framework serves as a basis for meta-responsibility that is not far-fetched from RRI's origins.

Building on an extensive tradition of philosophical literature on responsibility, Pellizzoni [12] conceptualised the responsibility elements on the basis of two facets: justification (i.e., how an actor reasons his or her behaviour), and imputation (the possibility of tracing an action back to its agent as the causal factor). These facets are visualised as the axes in Figure 2.1.

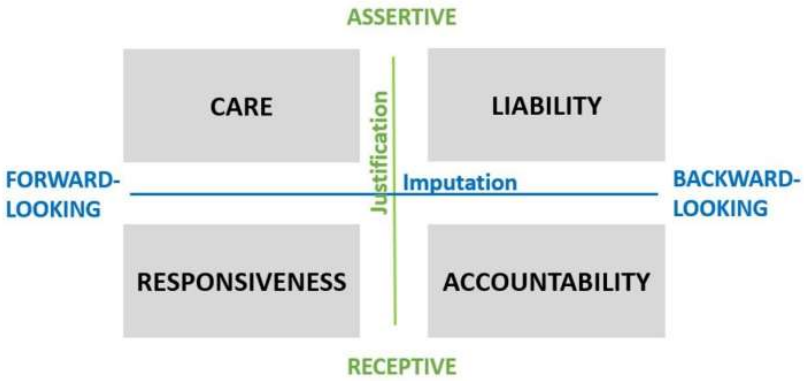

Figure 2.1. A framework presenting the elements of responsibility, modified into the R&I context based on Pellizzoni [12]

To render the framework more descriptive of the R&I context, we elaborate the facets of justification and imputation in a somewhat different fashion than Pellizzoni. Regarding justification, we take as a point of departure the challenge of how to justify acts in light of the high uncertainty that inherently characterises R&I projects. As future-oriented activity, not only is the outcome of an R&I project unclear, but also its impacts on the social and natural environment are difficult to predict due to complex cause-consequence relations [4,6]. Moreover, the very the meaning of a "good outcome" can shift, e.g., with changes in consumer demands or societal values [1]. To pinpoint how this uncertainty can be addressed in R&I, we apply the following dichotomy:

- In assertive justification, it is known what is right or wrong (or it is believed to be known).
- In receptive justification, it is less clear what is right or wrong (and there is awareness of this uncertainty).

Imputation is a close synonym for "allegation" and refers to the event of tracing an action back to its originator. With this regard, Pellizzoni makes a distinction between forward- and backward-looking responsibility, and this dichotomy has been further evoked by Pellé and Reber [6] and van de Poel and Sand [4] in the context of inventorying responsibilities in R&I. On the one hand, R&I essentially fosters the opportunity to "transform the future" towards what is deemed right and desirable. In line with van de Poel and Sand [4], such actions are driven by a forward-looking attitude of improving current

conditions based more on virtue and "collective stewardship" and less on concerns about finger-pointing if the act turns out to be unsuccessful. On the other hand, as innovation involves risks and unexpected twists, actions can also be driven by a backward-looking safeguarding that no harm will be done. This mindset is accompanied by an expectation that acts will eventually be evaluated, with attribution of blame, punishment (or praise) to the agent [4]. In synthesis:

- A forward-looking mindset is driven by a prospective aspiration to improve the current state of affairs (and if failing, trying better the next time).
- A backward-looking mindset is driven by (the expectation of) retrospective evaluation on the possible harm (or benefit) caused by the action.

From this systematics, a set of four understandings for responsibility unfolds as illustrated in Figure 2.1. In the particular context of R&I, we attribute the following definitions to these elements:

- Care, as the assertive, forward-looking element of responsibility. Care-motivated actions are characterised by already knowing what a good and desirable outcome is (i.e., assertiveness), and working for improving the current state of affairs to reach this outcome (forward-looking)
- Liability, as the assertive, backward-looking element of responsibility. Liability-motivated actions focus on seeking compliance with society's set rules that are known and applied during the act (assertiveness), and avoidance harms and risks (backward-looking).
- Accountability, as the receptive, backward-looking element of responsibility. Accountability-motivated actions involve contemplation of what would be the right thing to do according to one's best knowledge at a given time (receptiveness) and are characterised by keen focus on the expected impacts of these actions (backward-looking).
- Responsiveness, as the receptive, forward-looking element of responsibility. Responsiveness-motivated actions involve reflection on what is right and desirable (receptiveness), while simultaneously improving the status quo (forward-looking) in the form of trying and learning. Responsive activity is open-ended in the sense that the shape and direction of the outcome is constantly being reassessed.

To lend concreteness to the abstract notions, Table 2.1 elaborates on each element of responsibility. The first set of examples is provided by Pellizzoni [12], while in the second set, we hypothesize examples in the private sector context. While Pellizzoni typically explicates through negation (what is not responsible), our hypothesized examples also introduce positive interpretations (what is responsible).

Table 2.1. Elements of responsibility elaborated

Element of responsibility	Characterised by	Elaborations by Pellizzoni [12]	Hypothetised elaborations in the private sector context
Care	Knowing what is a good outcome (assertive), and working to advance the current situation toward it (forward-looking).	The parents take care that their child gets enough food. (It is known that children need food, and parents are supposed to take care of their children).	A company cuts carbon dioxide emissions as part of its sustainability strategy, so as to assume care of future generations.
Liability	Compliance with society's set and known rules (assertive), avoidance of harms and risks (backward-looking).	The parents are deemed liable in court for their child's malnutrition. (it could be proven that the parents' neglect had led to the malnutrition.)	A company is judged to be liable for the financial losses of another company due to a patent violation.
Accountability	Weighing what is the right way to proceed (receptive), driven by contemplation of the impacts of the actions (backward-looking).	The parents put the child in a good but expensive school. To pay for this, the parents need to work long hours, and the child becomes lonely and depressed. Can the parents be held accountable; Were they supposed to know the impacts of their choice and be able to choose correctly?	A Chief Executive Officer (CEO) is accountable for a company's shareholders, through the Board, for recent financial results. (In a CEO position (s)he is supposed to know how to make sound decisions.)
Responsiveness	Reflection on what is right and desirable (receptive), by 'trying and learning' simultaneously with improving the status quo (forward-looking).	The parents strongly oppose the child's desire to become an artist. The child chooses another career and becomes unhappy. The parents were not responsive to the child's emerging aspirations, and in this sense are responsible for their child's condition.	An R&I team is responsive to the expected impacts of their future product on society. The team consults stakeholders with help of a product prototype, which is then further designed to better fulfil the identified needs.

To explore how the elements of responsibility become manifest in corporate R&I settings, Section 2.3 presents the settings and design of a case study that was conducted for inventorying responsibilities in an ongoing R&I project.

2.3. Methodology: Mapping responsibilities in a case study

The case project, named Bio2X, is an R&I project within the company Fortum—a large-size enterprise headquartered in Finland. Bio2X was chosen as the case project of this study for reasons of accessibility (the main author working in the case project), and its relatively early stage (implying high uncertainty, relevant to the scope of this study).

Bio2X is developing a biorefinery concept to convert lignocellulosic biomasses, such as wood and agricultural straw residues, into their structural components (i.e., fractions) by employing conversion technologies called fractionation technologies. The fractions—cellulose, hemicellulose, and lignin—would then be further manufactured into various bio-based products, in commercial partnerships with industrial manufacturers and consumer brand owners.

At the time of the study, the main milestone ahead for Bio2X was to prepare an investment proposal for building a pilot-scale biorefinery plant. In the so-called “upstream” part of the project, the Bio2X team was working with upscaling the fractionation technologies towards the pilot scale in order to get sufficient proof of technical feasibility for the investment proposal. On the “downstream” side, the aim was to establish demand for Bio2X’s fractions among manufacturing industries. The team members were engaged in networking with companies, e.g., in the textile, construction, and cosmetics industries, that were testing the use of Bio2X’s fractions in manufacturing industrial and consumer applications.

For supplementary background, we highlight features of Bio2X that frequently appeared as characterising the team’s work.

At the time of this case study, Bio2X was a relatively **early-phase** project, termed as the “pre-engineering phase” by the team members. In terms of a typical innovation process model [5], the project, to a major extent, was in the exploration stage (applied research) and to some extent in the development stage (pilot and demonstration), with the implementation stage (delivering value to consumers and society) still years ahead.

Characteristic of early-phase R&I is **high uncertainty** regarding the project's outcome [1,13]. In the Bio2X case, there were multiple open product and technology options, as well as uncertainty as to what extent the fractions produced on a small scale were representative of large production scales. In the company's R&I structure, the project was at the stage of becoming an "internal start-up", denoting a further uncertainty about the project's continuation, to some extent similar to external start-ups [14]. The Bio2X's managers devoted a considerable share of their time to "selling" the project within the company, ensuring Bio2X a role in the corporate business strategy, and attaining continued funding for the project. For instance, at the time of the interviews, Bio2X members in managerial positions were involved in corporate strategic discussions, as the company was updating its growth strategy.

Another characteristic of Bio2X was its highly **collaborative** working model. Bio2X did not possess research facilities of its own, instead experiments and scale-ups were conducted at the collaborators' premises. The fractionation technology developers were start-up enterprises, financially supported by the company to enable technology scale-up and working closely with the Bio2X team members. Moreover, the business models envisioned for the full-scale biorefinery were based on the physical co-existence of several industrial partners adjacent to the biorefinery, for further manufacturing the fractions into end products (i.e., an industrial ecosystem). A **high degree of novelty** is a known driver for collaborative ways of working [15]. In general, the bio-based manufacturing sector is still largely an emerging one. In Bio2X case in particular, bio-based manufacturing was largely a novel territory for the company, which was undergoing strategic renewal to expand beyond its current business area of energy generation. Team members expressed the view that Fortum and Bio2X were "accelerators" of the emerging bio-based industrial sector: Being a large enterprise coming from outside the established manufacturing sector, there are both resources and motivation to upscale novel biorefining technologies for debottlenecking industrially relevant scales of bio-based materials for the final product manufacturers.

2.3.1. Materials and methods

Data was gathered from 13 semi-structured interviews of approximately 90 minutes each, conducted over a period of 4 months in 2018. The semi-structured protocol was chosen in light of the exploratory nature of the study, as it permits the respondents

"to talk about what the respondent wants to talk about, so long as it is anywhere near the topic" [16] (pp. 48–49). The questions were grouped into five sets (see Appendix A). In the first set of questions, the interviewees were asked to describe the project and their tasks in it, what particularly motivated them in the project, and what their main concerns relating to the project and its outcome were. The next question set explored how the respondents understood "corporate responsibility", how Bio2X links to corporate responsibility, and what "societal and environmental impacts" the respondents envision would result from the project—both positive and negative. In the third set, the respondents were asked to describe the current stage of the project, and how it is like to make decisions at this stage. The fourth set explored how and to what extent societal and environmental impacts had been taken into consideration and eventually into decision-making. Finally, the interviewees were asked about the stakeholders and ways of working with them. The questions were ordered in a sequence allowing a good "flow" (easy transition from topic to topic) as well as free association before serving more specific (and in that sense steering) questions.

There were 13 interviewees in total, comprising of 7 team members (project managers, technology experts, trainees), 4 external consultants working for the project (3 with business and marketing background and 1 with academic background), and 2 "internal stakeholders" from other units of the company (1 sustainability expert and 1 from upper management).

The interviewees were chosen and contacted by the main author who was also the interviewer. Regarding the sampling method, all the team members working in Bio2X at the time of the study were chosen as interviewees (save the interviewer). With the external experts and internal stakeholders, the purposive sampling method [16] was followed: firstly, to gain a more diverse outlook on the project by increasing the number of interviewees, and secondly, by bringing in insights from their particular fields of expertise. The interviews were recorded, and the recordings were translated and transcribed into English. For qualitative analysis, the transcripts were coded and sorted using the MAXQDA coding tool. The coded text fragments across different transcripts were then harvested into excerpt files, gathering themed data across different transcripts. The analysis evolved iteratively, as Weiss [16] describes, through several coding rounds during which the initial focus and hypothesis were gradually refined, with more and more data fitting into the established codes. That is, using excerpt files, "minitheories" were formulated, based on which new codes were designed and a new coding round was set forth [16].

The initial focus, and hence the basis for planning the question set, was to explore how responsiveness as the "R&I-type of responsibility" (i.e., forward-looking and uncertainty-receptive) becomes operationalised in an R&I project. However, it quickly began to emerge from the data analysis that the R&I context was characterized by a constant dynamic between forward-looking, backward-looking, assertive, and receptive dimensions of responsibility, appearing as dependencies, tensions, synergies, and gaps between different elements of responsibility. This observation lead to the reformulation of initial research question and the application of a new coding set based on Pellizzoni's [12] four responsibility elements (Figure 2.1). The evolution of the coding sequences is depicted in Appendix B.

Finally, interpretation of the interview results also involved using an adaptation of the "embedded ethicist" method [17]. The setting of "employed ethicist", with one of the authors (the interviewer) working on the case project, also enabled observations on the project's development after the interview period. This allowed some glimpses into the validity of the findings and recommendations of this study in light of later project stages.

2.4. Results and discussion: Meta-responsibility outlook on corporate R&I

Through the lens of the responsibility framework (Figure 2.1), data analysis unveiled a coexistence of forward- and backward-looking, receptive and assertive aspects of responsibility in the team's goals, motivations, concerns, working methods, activities and decision making. Often, different responsibility elements became distinguishable in relation to one another, revealing tensions and trade-offs but also synergies, in between. To better depict and further explore the coexistence of responsibility elements, Figure 2.2 proposes a meta-responsibility map for R&I. It portrays three major dynamics derived from the case study data between the responsibility elements: accountability–responsiveness, care–responsiveness, and liability–responsiveness.

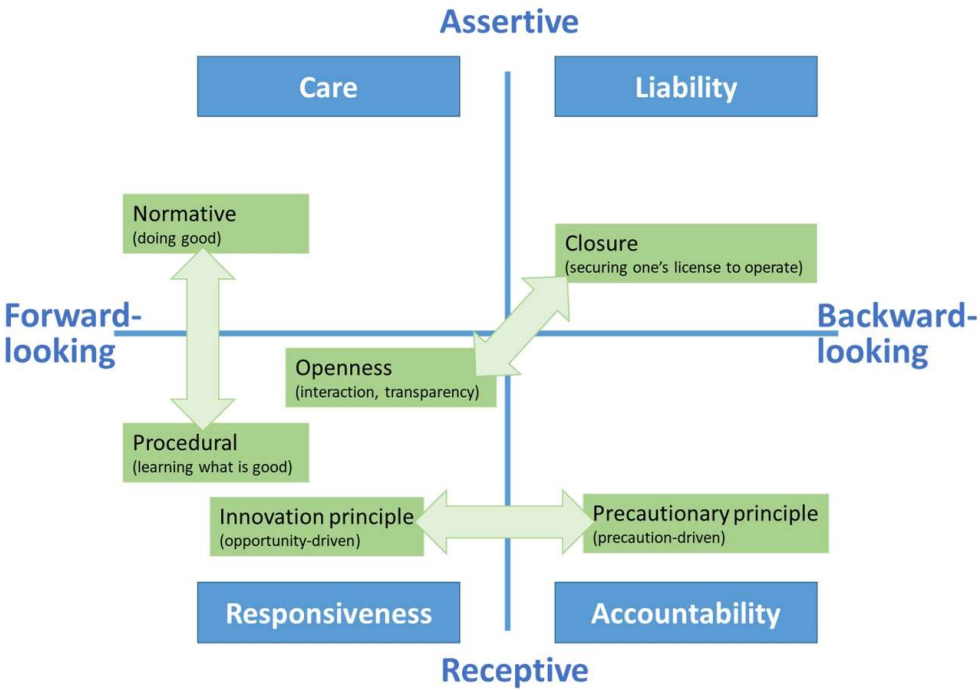

Figure 2.2. A meta-responsibility map for inventorying responsibilities in R&I projects.

We identify the following features in the meta-responsibility map that speak for its practical relevance in R&I, as well as make a theoretical contribution to existing RRI literature on meta-responsibility. First, the map brings various and sometimes contradicting principles, expectations and obligations under a common terminology, responsibility, and thus supports their alignment in R&I work. In particular, as explicated in Section 2.2, the map incorporates different stances to coping with the uncertainty faced by R&I practitioners. Furthermore, the map stems from our empirical finding that the elements of responsibility became most tangible when contrasted (or opposed) to each other in the interviewees' reflections. The focus on dynamics between elements of responsibility, instead of merely focusing on individual elements, can support R&I teams for instance in situations of decision-making involving contradictory expectations.

That being said, it is evident that there are aspects in responsible innovation, which our framework does not directly address, nor cover to a sufficient degree. There is literature on meta-responsibility that is more targeted, for instance, at specifying *who* in the R&I is exactly responsible for whom [7], or, at evaluating the degree to which the

identified responsibilities actually become allocated to innovators in R&I units [4] and contribute to the company's overall performance [11].

The remaining Section 2.4 presents and discusses the interview results which led to formulation of the meta-responsibility map. First, Table 2.2 gives an overview on how the conceptual elements of responsibility appeared in light of the practices of Bio2X. It does so by formulating three overall challenges based on the interview responses, which point to the tensions (in Figure 2.2) between different understandings of responsibility. Further, Table 2.2 links these challenges with related themes and discussions in the RRI literature. Finally, bringing together theoretical concepts and practice, Table 2.2 puts into effect the responsibility elements as approaches for managing these challenges.

Table 2.2. Overview on how the conceptual elements of responsibility appear in light of the case study.

Responsibility elements at stake	Challenge emerging from the case project	Related themes in RRI	Approaches in the case project for managing the challenge
Accountability – Responsiveness	How to strike a balance between risk-taking and precaution in early R&I, given the uncertainty about outcomes and impacts?	Precautionary principle vs. innovation principle [5,12]. Anticipation of the impacts of innovation [2,3].	**Accountability**, as: Mitigation of uncertainty by knowing the impacts before deciding what to do. **Responsiveness**, as: Learning about and addressing impacts whilst doing.
Care – Responsiveness	How to be sure that R&I project is doing the right thing, given the novelty of technologies, products and industrial sector?	Normative vs. procedural approach to responsible innovation [3,18,19]. Reflection about the goals of innovation [2,3].	**Care**, as: Acting based on given definition for what the right impact is. **Responsiveness**, as: Practice of actively (re)assessing what the right impact is.
Liability – Responsiveness	How to accelerate emergence of a novel industrial sector, while also safeguarding one's own area of operation in it?	Inclusion, interaction and transparency, vs. maintaining information asymmetry for competitive advantage [13,20].	**Liability**, as: Protecting oneself against losing one's assets. **Responsiveness**, as: Openness and dialogue for advancing joint goals.

These results are presented and discussed more in detail in the subsections below. Alongside, we discuss the wider applicability of the meta-responsibility map in supporting responsible innovation.

2.4.1. Accountability–Responsiveness: Precaution versus the innovation principle

R&I, being a highly uncertain activity, is about balancing between risk-taking and exercising precaution. In the RRI context, this dynamic has been brought out as a dichotomy between precautionary and innovation principles [5]. In responsibility terms, these principles appear as manifestations of accountability and responsiveness, respectively. As receptive elements they both acknowledge uncertainty but stand in contrast as to how the uncertainty is addressed. Accountability, as a backward-looking element, favours eliminating risks by knowing the impacts before acting (i.e., precaution), whereas responsiveness as a forward-looking element focuses on opportunities behind the risks and relies on "learning by trying and failing" in seizing them (i.e., innovation). As Dreyer et al. [5] point out, too much precaution may kill or detrimentally slow down innovation, while too much of overhasty trial and error may backfire as well.

2.4.1.1. Meta-responsibility supports R&I in balancing between innovation and precaution

We suggest that meta-responsibility can help R&I teams in discussing differing and sometimes opposing views on "risk or precaution" in a constructive way. Both viewpoints can become more understandable as efforts of assuming responsibility over an R&I project's outcome, in situations of high uncertainty. The Bio2X team frequently brought up the uncertainty surrounding their early-phase biorefinery project, which indicates an overall receptive mindset. The project was at the stage of exploring several product, partner, and technology options, thus "*opening new doors to be able to decide through which to continue*". Moreover, many respondents brought up the fact that the small-scale experiments and product prototypes were, always, believed to be only limitedly representative of the eventual large-scale biorefinery. However, the interviewees differed in their views on how to carry on under such uncertainty. On one hand, there was reflection on the risk of giving overly optimistic prospects too soon, e.g., to funders or industrial collaborators:

"Do we go with too much promising? Now that we're so at the beginning . . . building too high expectations."

At the other extreme, some interviewees expressed concern about proceeding too cautiously, slowing down development and encumbering financial resources for the development work:

"I strongly believe in creating challenging and inspiring visions for the future, and (then) doing everything to get there. If you don't dream at all and don't have a good story, it's hard to get people excited, even within the company internally."

"Typically, at this stage in the project, there strikes a fear to promise anything, whereas right now, we should be promising big-time."

In light of meta-responsibility: while some respondents raised a concern about unaccountability (not being able to deliver the indicated impacts), thus taking a backward-looking perspective, there also appeared concerns about unresponsiveness (not addressing an opportunity for fear of failure), marking a more forward-looking stance. Observable in individual remarks during the interview period, this questioning later became more explicit and diverse in the team's internal discussions as Bio2X was shifting from the early project phase closer towards implementation, involving crucial decisions about the eventual biorefinery setting and business model. The right timing for making such decisions became actively debated, in light of how much uncertainty can (and should) be stomached; for instance, when choosing key commercial partners or main end products. In terms of meta-responsibility, seeing the differing viewpoints as complementary aspects of responsibility—already at a very early project phase—could provide a "responsibility frame" for later-stage discussions. For instance, meta-responsibility could come in the form of collective reflection on how to facilitate inherently risky innovations (responsiveness) without "building too high expectations", or, how to take sufficient precaution (accountability) without a "fear of promising anything".

2.4.1.2. Meta-responsibility shows an early R&I project in light of its eventual timeframe

Meta-responsibility helps in comprehending an early-phase R&I in light of both its current and subsequent responsibilities. In an early-phase R&I, the forward-looking

elements of responsibility are prevalent in probing the impacts of the still-far-ahead outcomes of innovation. At later R&I stages, initial uncertainty reduces and the temporal focus shifts from the future closer to the present. This enables a wider adoption of also backward-looking responsibilities, such as accountability for profit generation and increasing contractual liabilities. In the case of Bio2X, the meta-responsibility outlook revealed both forward-looking stances of an early-phase project, as well as an "anticipation" of the future's backward-looking responsibilities.

At Bio2X, the interview responses revealed an abundance of management practices (i.e., actions, decisions, working methods) for mitigating perceived uncertainties. Overall, the team's approach in addressing uncertainties clearly inclined towards responsiveness. Activities were distinctly about resolving uncertainties *while* doing, by piloting through gradual up-scaling; improving process parameters through trying-and-learning, product prototyping and experimentation with industrial manufacturers; and maintaining constant dialogue with key stakeholders such as consumer brand-owners representing the consumer perspective.

> *"We need to see how the technologies work in upscale. As long as they are concepts on paper or test tubes in the lab, it's not possible to know. We need to pilot and experiment all the way to the end product."*

The occurrence of forward-looking practices is logical given Bio2X's early phase. Many respondents also remarked that, in the end, some uncertainty is inevitable in innovation and needs to be accepted, as *"successful innovation is also about luck and coincidence"*, *"you can't know everything in advance"*, and *"things also need to happen at the right time"*.

On the same note, backward-looking methods such as impact assessment (accountability) were referred to by many Bio2X respondents but seen as largely inapt given the project's early phase, at least in terms of playing out to their fullest extent. For instance, life-cycle analysis (LCA) was not perceived as relevant in the current batch-mode biorefinery pilot, as the properties of material streams (e.g., wastewater volumes and chemicals accumulation) could only be verified later during continuous operation mode.

However, many of Bio2X's activities, during the early phase of the project, appear more coherent when seen as initial attempts to assume "pre-accountability". With the

team aware of the approaching backward-looking duties and obligations of the near-commercial phase, they were glimpsing into the project's full-scale impacts with the means available at the time. For example:

> *"We can simulate a continuous process in batch-mode, to estimate (environmental impacts,) for example water consumption. However, the whole truth will reveal itself only at the demo-scale."*

Similarly, in the absence of representative empirical data, the team was conducting a "pre-LCA" study on lignocellulosic textile fibre production, using literature data and benchmarking with the environmental footprints of existing fibre technologies. Moreover, partnering with more established bio-manufactures, having pre-industrial trials, enabled taking considerable leaps from the early stage.

> *"Our technology suppliers are already in pre-industrial trials; the partners' stage also defines where we are."*

It appears that the need for such pre-accountability is accentuated in industrial sectors like Bio2X's. Biorefining is an asset-heavy industry, which implies that mitigating uncertainties via process upscaling demands considerable investments in production equipment and is thus slow and expensive. Furthermore, as bio-based value chains are long multi-party assemblages, it appears practically impossible to make meticulous comparisons between all open product trajectory options, e.g., regarding their environmental footprints. In Bio2X, the number of potential product options was made more manageable by choosing a spearhead product trajectory—textile fibres—whose requirements were given the highest relevance in biorefinery process design. This left a lesser degree of freedom for other fractions, narrowing down product options and enabling a more thorough assessment of at least some product pathways, while positioning the assessment of others for later stages.

Table 2.3 summarises the practices for mitigating uncertainties that were referred to by the Bio2X interviewees, some of which have been discussed above. In line with Table 2.2:

- **(A)** is used to mark practices that are characteristically about accountability, in that they focus on knowing impacts before deciding what to do.

- **(R)** marks practices of responsiveness, as learning about and addressing impacts whilst doing.
- In addition, **(R/A)** refers to practices that do not clearly fall into either of the above, but rather mediate in between (i.e., "pre-accountability" as anticipation of future accountabilities).

In summary, meta-responsibility broadens the scope of responsibility during an early-phase R&I in that the activities of anticipating future responsibilities, beyond immediate responsibilities, also become encompassed. Regarding RRI as a meta-responsibility approach, this perspective makes RRI more attentive to the (near-)commercial responsibilities of corporate R&I, which, as pointed by Dreyer et al. [5], have so far remained poorly addressed in RRI. In particular, the mindset of "pre-accountability" in cases like Bio2X is a call for RRI proponents to advocate and further develop tools of *anticipation*, to support corporate R&I in exploring their future responsibilities for the impacts of the prospective full-scale innovation.

Table 2.3. Management practices for mitigating uncertainty regarding an R&I project's outcomes.

(R) Responsiveness: Learning about and addressing impacts whilst doing	(R/A) Mediating practices: Anticipation of future accountability	(A) Accountability: Knowing the impacts before deciding what to do
Practices related to R&I management and strategies		
• Iterative rather than linear project model • Learning-by-doing, gradually focusing hypotheses • Many simultaneous product/process trajectories (plan-B's) • Design thinking: inclusion of sustainability criteria in early process design	• Choosing one spearhead product trajectory (to narrow down options) • Temporal prioritisation: only few product trajectories at a time	• Stage-gate process model including showstoppers
Practices related to piloting and experimentation		
• Piloting biorefinery • Prototyping and experimentation with downstream product manufacturers • Proceeding gradually towards more challenging raw materials/products	• Simulation of continuous process in small-scale batches	
Practises related to assessments and evaluations		
• Studying consumer and societal trends • Market studies	• "Pre-LCA" based on estimated and literature data • Applying higher (sustainability) standards for novel biorefinery than in the existing ones	• Full LCA (close to the implementation phase) • Benchmarking to existing operations in the sector • Following certificates and standards
Practices related to partnerships		
• Open communication with stakeholders • Fostering trust among partners	• Collaboration with partners having (pre-)industrial trials	• Auditing • Requiring certificates and standards
Dealing with residual uncertainty		
• Accepting "you cannot know in advance" • Leaving space for luck and coincidence • Trusting one's partners • Trusting that over time, technological development will solve uncertainties		

2.4.2. Care–Responsiveness: A normative vs. procedural approach to responsible innovation

R&I, as a future-oriented activity, is focused on transforming the current state of affairs towards what is seen as more desirable. However, determining what a desirable outcome is may not be that straightforward. While the dynamic between accountability and responsiveness relates to knowing about the impacts of an innovation trajectory, the interplay between care and responsiveness involves a more profound questioning as to whether one's understanding of what constitutes good impact is, at the outset, "correct" or "right" (e.g., corresponding to societal perceptions or consumer needs).

As summarized by Blok et al. [18], RRI builds on two fundamental approaches in determining what a good impact of innovation is. The first one is the normative approach by von Schomberg [19], applying commonly agreed norms and principles as "normative anchor points" for R&I, such as "sustainability" and "social justice" in the European Union treaties, or a set of sustainability goals in a corporate strategy. In contrast, the procedural approach promoted by Owen et al. [3] highlights the need for innovators to continuously reassess the right impacts of innovation, e.g., by dialogue with its stakeholders, with norms less set in stone. In light of the responsibility framework, we suggest that the normative approach is an alias for care, whereas the procedural approach resonates with responsiveness. Being forward-looking elements, they are both driven by an aspiration to improve the current state of affairs, but whereas the assertive element of care is welcoming to fixed definitions for right impacts, responsiveness as a receptive element emphasizes the importance of constant checks for staying on-track towards what is a desirable innovation output.

Practical R&I work involves balancing between the normative and procedural. For example, highly novel and disruptive innovations may bring about societal disagreements regarding their desirability, calling for a broader and inclusive reflection on needs and impacts e.g., through stakeholder dialogue [21]. Other occasions may favour a more normative approach. Some innovations enjoy a broader social consensus regarding their desirability [18]. Moreover, stakeholder engagement is not a cure-all, as different views can conflict without providing a clear trajectory, or for practical reasons such as it being too time-consuming [22]. Furthermore, stakeholders may be unwilling to become involved in R&I activities [22].

2.4.2.1. Meta-responsibility to expose implicit concerns regarding R&I outcomes

We propose meta-responsibility as one means to maintain attention on an R&I project's wider impacts. It can trigger discussion on implicit concerns and reservations as to whether an R&I project is "doing the right thing" and aid in determining whether to adjust the project's goals and directions. In this, meta-responsibility acknowledges both the normative (knowing what is a good impact) and the procedural (learning what is a good impact) standpoints as strategies for taking responsibility for a project's trajectory and can stimulate reflection on their right balance.

In interviewing Bio2X members, the theme of "good impacts" was broached by inquiring about wider societal impacts that the respondents envisioned the biorefinery would have in the future, and how such impacts (e.g., on environment, employment) were considered and discussed overall in the project. Both normative and procedural standpoints were expressed in the interview responses. On one hand, corporate sustainability strategy provided a normative anchor point for many respondents:

> *"The company's strategy is to be a clean technology company and to boost the use of new technologies that burden nature and society less than the existing ones. In this way, Bio2X was actually born and our meaning comes from there. We are serving that vision."*

> *"The company's sustainability goals are very progressive and ambitious and well in line with my own (values)."*

On the other hand, among some respondents the interviews triggered a more receptive (procedural) reflection on the difficulty of exhaustively defining what "sustainable" in biorefining entails. This corresponds to findings by Asveld and Stemerding [21] regarding ambiguity in the bioeconomy: Complex indirect land-use impacts coupled with diverging values and priorities make it hard to falsify or prioritise one sustainability argument over another. One interviewee had observed such ambiguity in the argumentation for and against using stem wood in bio-based manufacturing:

> *"Building the concept (of wood-based biorefinery) sustainably, when you see it on paper it's 'OK we can go with this', but how to justify it to ourselves and to stakeholders—it's a challenge in my opinion."*

Moreover, the consumer demand for bio-based manufactured products was perceived as somewhat ambiguous owing to their general novelty:

> *"Compared to biofuels, there are no clear existing markets, regulations, and obligations (for bio-based manufacturing). That makes the discovery of the demand-side motivation not as clear as with fuels."*

Furthermore, while most respondents brought up sustainability as an important motivator for the project, it was also contemplated whether—somewhat paradoxically—sustainability as a strategic imperative was so much "in the spine" that it had become an axiom.

> *"Environmental aspects form a basic motivation for what we do. Maybe we don't think about it every day; it's so much in our spine."*

> *"I've noticed that we tend to take for granted that things are responsible."*

Altogether, the very act of interviewing sparked reflection among the team members on the project's initial assumptions and wider societal impacts. In that sense, interviewing became a practice of meta-responsibility, supporting responsible R&I by giving voice to implicit concerns about an R&I project's goals and directions. Here, meta-responsibility enhances reflection on the impacts of R&I—a foundational aim in RRI and in related approaches such as Midstream Modulation [23].

Besides reflection, meta-responsibility can also aid in identifying management practices for keeping the innovation "on track" with fulfilling positive societal impacts. In the Bio2X case, an array of both normative and procedural means was identifiable. Normative anchor points included, for instance, fixing the project's aims to corporate strategy-level sustainability guidelines, which for their part are rooted in addressing Grand Global Challenges such as climate change. Regarding the procedural approach, stakeholder involvement of brand-owners was identified as a means to discover consumer stances on novel bio-based products. However, alongside this, it was also mentioned that normative strategic guidelines are needed as *"consumers may want all shiny and glittery, and such products can be difficult to (sustainably) recycle*".

Interviewees also pointed out that ultimately some uncertainty is inevitable in R&I, which emphasises the importance of open communication:

"Is there something we don't see ourselves that leaks out in terms of sustainability? To recognize stretches of weak ice and speak them out: 'these are the handicaps of our processes'. Someone will dig them out anyway."

Finally, technological development appeared as a means to bypass some of the observed ambiguity regarding sustainability, for instance, in the use of stem wood in bio-based manufacturing:

"There is a lot of recycled wood in the world. Could it also be used as raw material in our processes? Why wouldn't it be a good time to start a small study, first the literature and then the experimental."

This particular reflection became an incentive for designing a study on the use of recycled wood in the fractionation process, which was eventually conducted later in the project. In retrospect, this exemplifies how meta-responsibility can create systematics for identifying and then addressing "stretches of weak ice", particularly during early stages when innovations are still well amenable to modifications.

Table 2.4 summarises the management practices referred to in Bio2X for keeping on track with the "right impacts" of innovation, some of which have been discussed above. In line with Table 2.2:

- **(C)** is used to mark practices that are characteristically about care, in that they justify actions based on knowing in advance what a right impact is.
- **(R)** marks practices of responsiveness, in the form of actively (re)assessing what a right impact is.
- In addition, **(R/C)** refers to practices that do not clearly fall into either of the above, but rather mediate in between (i.e., normative-procedural interaction).

Table 2.4. Management practices for mitigating uncertainty regarding an R&I project's outcomes.

(R) Responsiveness: Actively (re-)assessing what the right impact is	(R/C) Mediating practices	(C) Care: Acting based on given definitions for what the right impact is
Practices related to R&I management and strategies		
• Iterative rather than linear project model • Learning-by-doing, gradually focusing goals	• Normative-operational interaction: Collaboration between the R&I, Strategy, and Sustainability units • In situations of high uncertainty, apply higher-level standards "just in case"	• Anchoring of the project's aims to corporate strategy-level guidelines • Corporate strategy anchored to Global Grand Challenges (e.g., climate change) • Benchmarking: Anchoring the project's aims to the standards of the industrial sector
Practices related to stakeholder engagement		
• Involving stakeholders for mutual learning regarding the R&I project • Applying local expertise for understanding diverging needs at different locations	• Involving brand-owners (or other established actors) as represent-atives of consumer/ societal demands • Checking from stakeholders that the project's aims are communicated clearly (e.g., to end consumers) Learning from external experts: consultants, attending conferences	• Involving stakeholders for informing them about the R&I project
Practices related to assessments and evaluations		
• Team/self-reflection on what is responsible/ sustainable • Consumer trend / market demand assessments		
Dealing with residual uncertainty		
• Awareness that "we do not know everything • Accepting "good enough" • Openness about unclear and ambiguous issues • Technological development to get around dilemmas and disagreements about right impacts		

2.4.3. Liability–Responsiveness: Protecting one's assets vs. speeding up sectoral change

From its outset, the private sector is characterised by information and power asymmetries that are sought out and maintained for the sake of securing competitive advantage. Somewhat contrary, RRI initially defines responsible innovation as a "transparent, interactive process by which societal actors become mutually responsive to each other with a view to the (ethical) acceptability, sustainability, and societal desirability of the innovation process and its marketable products" [19] (p. 19). Bringing together these two principles has been a major point of contention in the RRI studies on private sector R&I [13]. Openness "creates an inherent feeling of lack of control over the processes and results of the innovation", and interaction can be restricted by the risk of knowledge (ownership) leakage to competitors [20] (p. 151). However, reducing information asymmetry can also bring about considerable benefits. Sharing information, resources, and partnerships can accelerate sectoral renewal beyond what is achievable by one company alone, for example, in transforming an entire sector towards more sustainable technologies and practices [9,20]. The value of stakeholder interaction on a product's success is well acknowledged among companies. For example, different forms of Open Innovation are well-known working methods in some industries [24].

2.4.3.1. Meta-responsibility in bridging between societal goals and competitive advantage

RRI has recognised the difficulty in bringing together closure and openness in R&I but so far provides little advice on how to address it. In light of this case study, we suggest that meta-responsibility can facilitate responsible innovation by bringing the co-existing, and somewhat conflicting, tendencies of closure and openness under the terminology of responsibility.

While Bio2X was building the biorefinery concept and its emerging value chains on the basis of active collaboration between several institutions (companies, start-ups and research institutes), it also identified certain risks in this approach. The need for finding balance between closure and openness was voiced most explicitly by one interviewee:

"When you operate in (a business) ecosystem, you accept that not everything is yours. But how to secure what's yours sufficiently so that you have a freedom to operate in where you build your key success factors?"

On the one hand, many interviewees highlighted the fact that the emergence of bio-based manufacturing sector would be extremely slow without *"linking actors and scaling up technologies together"*. At this point, the company's role as an "accelerator" was brought up by most respondents. On the other hand, the accelerator role was seen to be accompanied by the risk of losing ideas, generated knowledge, and decision-making power beyond the company's control. Some of the respondents brought up concerns about *"someone taking our ideas and blocking us out from the sector—in case we're the only one trying to open up"*. For one respondent, this risk was especially pronounced given the early phase of the project—while the team is still evaluating several product portfolios and business model options, they simultaneously *"need to look 10–20 years ahead to be able to reserve what you want for yourself"*.

In view of meta-responsibility, the interplay between openness and closure resonates with that found between responsiveness and liability. Responsiveness takes responsibility for progressing joint societal needs and goals, in Bio2X's case, the acceleration of sectoral change towards bio-based production, via promoting information sharing and interaction between industrial manufacturers, consumer brand-owners, and other stakeholders. Liability imposes responsibility for protecting oneself against losing one's assets, to secure the legal and contractual freedom to operate by, e.g., restricting information sharing and protecting intellectual property through patents (and respecting others' intellectual property to avoid legal measures).

We argue that meta-responsibility can facilitate responsible R&I in that it recognises both sectoral acceleration and preserving one's own possessions as displays of responsibility (to shareowners, further to society, and to other legal entities). On this basis, meta-responsibility can support R&I teams in recognising tensions and synergies amid those objectives and, subsequently, in applying management practices for balancing between. Similar to "risk or precaution", this thematic also became more explicit in the Bio2X team's discussions only after the interview period, fuelled by the approach of the pre-commercial phase involving crucial choices between biorefinery business model, process, and partner options. For instance, the trade-off of speeding up the biorefinery upscaling (Bio2X's role in the value chains being narrower) and that of generating and

applying intellectual property rights for Bio2X (taking more time) became actively discussed. With meta-responsibility, this and similar questions could already be systematically identified and explored at earlier R&I phases, to support decision making at later stages.

Many management practices already exist in corporate R&I for balancing between openness (responsiveness) and closure (liability) and were in use by Bio2X. For instance, regarding liability, the Bio2X team operated under Non-Disclosure Agreements (NDAs) and Material Transfer Agreements (MTAs) whenever the produced lignocellulosic fractions were being tested by industrial manufacturers.

> *"(Openness) requires securing our ideas and projects, be it patenting or other agreements, or NDA."*

Additionally, more responsive approaches and tools were identified and further ideated during the interviews:

> *"We could have cases functioning as open innovation. For example, with cellulose-based textiles, if we incorporate them into a publicly funded project and involve a number of start-ups and create (a business) ecosystem or company clusters."*

Also tied to responsiveness is the importance of building trust among stakeholders, another factor emphasised by many respondents. In line with Dreyer et al. [5] trust is an important accelerator in risky innovations, promoting "lean regulation and low barriers for scaling-up" (p. 10), as opposed to defining every detail through contracts. Finally, communicating a strategy of openness and encouraging others to do the same was mentioned as one means of mitigating the risks of losing control:

> *"(If we) speak out about the openness strategy as much as possible and that becomes a generally accepted approach, like 'we are ready for it, are you?' then it would at least mitigate the risk that someone would dare to steal from another."*

As a mediating practice between liability and responsiveness, "selective openness" appeared where certain topics are promoted jointly by the partner network while others remain exclusive:

"We clearly define what is our core, our spearhead, and what is free for others, thus setting limits for competition."

For instance, sustainability goals were seen as joint terrain and "an easily shareable topic", with which it is also easy to approach potential new partners. In light of earlier RRI studies on stakeholder engagement, selective openness can be of joint interest as R&I's stakeholders are often motivated not to become too closely involved in projects [22]. This setting opens opportunities for RRI to further develop practices of selective openness for corporate R&I that are in line with RRI's principles of inclusion and deliberation.

Table 2.5 summarises identified management practices in Bio2X for accelerating the formation of the bio-based manufacturing sector, while safeguarding its own area of operation within it. In line with Table 2.2:

- **(L)** is used to mark practices that are characteristically about liability, in that they focus on protecting oneself against losing one's assets.
- **(R)** marks practices of responsiveness, in terms of fostering openness and dialogue for advancing joint goals.
- In addition, **(R/L)** is used with mediating practices (selective openness).

Table 2.5. Practices for managing a corporate R&I project within (and as part of) an emerging industrial sector.

(R) Responsiveness: Openness and dialogue for advancing joint goals	(R/L) Mediating practices	(L) Liability: Protecting oneself against losing one's assets
Practices related to partnerships		
• Societal and sustainability goals as a shared terrain among partners • Building trust between partners • Right to opt out from collaboration	• Selective openness: Openness among partners except for the core competences • Clearly communicating what the core is and what is shareable with (or free for) others	• Contractual measures (e.g., NDA)
Practices related to R&I management and strategies		
• Open innovation models • Communicating the strategy of openness	• Clearly defining what the core is and what is shareable with (or free for) others	• Securing ideas through patents • Increasing technical knowledge about core technologies • Enhancing technology ownership via investments
Practices related to assessments and evaluations		
	• Scenarios of sectoral and market development • Reflection on the project's vision and role in the emerging business ecosystem	• IPR landscape assessments

2.5. Conclusions

In this paper we developed a meta-responsibility map for facilitating responsible innovation in corporate R&I. We began by itemising the extensive concept of "responsibility" into elements of care, liability, accountability, and responsiveness, with the framework by Pellizzoni [12], and further adapted this framework into being more attentive to R&I as a highly uncertain and future-oriented environment. With this framework in hand, using a case study, we set out to explore how theoretically formulated responsibility elements become operationalised in a corporate R&I project. In the resulting

analysis, elements of responsibility regularly appeared in interaction with one another, revealing tensions and trade-offs but also synergies in between. This finding led us to develop a meta-responsibility map elaborating the dynamics between responsibilities in corporate R&I settings.

We conclude that the meta-responsibility map can help R&I personnel to deal with the inherent uncertainty of R&I in a responsible way, in that it brings various and sometimes contradicting principles, expectations, and obligations under a common terminology of responsibility and thus supports their alignment in R&I work. In this particular case study, meta-responsibility brought to light challenges as well as solutions related to (i) balancing risk and precaution, (ii) exposing and addressing concerns about the goals and impacts of innovation, (iii) accelerating sectoral transition whilst securing one's own competitive advantage in it. With meta-responsibility, we were able to capture early voicings of these themes among the interviewees that subsequently became frequent topics of discussion during later project stages. Here, we propose that meta-responsibility adopted into early-phase R&I can support R&I throughout its trajectory, by bringing systematics for identifying different responsibilities, supporting deliberation on them, and mobilising practices for balancing in between them. As exemplified in Tables 3–5, companies already possess a wealth of approaches and methods for addressing different aspects of responsibility. Meta-responsibility can become a management approach for thoughtful application of these practices across the entire innovation process.

Regarding implications on RRI, the meta-responsibility map can enhance RRI's theoretical integrity as it links some of RRI's key themes and discussions with the terminology of responsibility. It does so by presenting the dichotomies of normative–procedural, precaution–innovation, and closure–openness as addressing different elements of responsibility. Secondly, meta-responsibility enhances RRI's relevance in corporate settings as it encompasses both early-phase (often forward-looking) and near-commercial (increasingly backward-looking) responsibilities, the latter of which have so far remained narrowly addressed in RRI. Lastly, systematic inventorying of responsibilities in an R&I project can pinpoint specific missing elements, enabling a more targeted and context-sensitive application of RRI's toolkit for increasing anticipation, reflection, and inclusion in R&I activities.

Our study obviously has its limitations. First, given its exploratory nature, the scope, result analysis, and formulation of meta-responsibility developed iteratively. This

implies, for instance, that the eventual research question was somewhat different than the original one used for designing the interview questionnaire. Adopting meta-responsibility in further case studies would make the approach theoretically more solid (by enriching understanding about interactions between responsibility elements) and empirically more diverse (by encompassing different types of companies, R&I project models and phases, as well as industrial sectors). Secondly, one of the paper's authors is employed in the case project under study, which brings in the question about the influence of this position in the research design, interviewing, and interpretation of the results. Having both benefits and drawbacks, the role of an "employed ethicist"—in parallel to that of an embedded ethicist [17] or embedded humanist [23]—definitely deserves further deliberation as a mode of conducting case studies and qualitative research.

Finally, the study brought out further research topics that were not possible to address within the limits of one paper. One such topic is to render the complex notion of "co-responsibility" more digestible by approaching it through meta-responsibility. This would enable explorations on how different elements of responsibility are distributed between different organisations along an entire product value chain or between units of an individual company. Another topic for RRI would be to further explore how the corporate raison d'être, accountability for profit generation, coexists with other aspects of responsibility in R&I projects.

References

1. Van de Poel, I.; Asveld, L.; Flipse, P.; Klaassen, V.; Scholten, V.; Yaghmaei, E. Company Strategies for Responsible Research and Innovation (RRI): A Conceptual Model. *Sustainability* **2017**, 9, 2045.

2. Lubberink, R.; Blok, V.; van Ophem, J.; Omta, O. Lessons for Responsible Innovations in the Business Context: A Systematic Literature Review of Responsible, Social and Sustainable Innovation practices. *Sustainability* **2017**, 9, 721.

3. Owen, R.; Stilgoe, J.; Macnaghten, P.; Gorman, M.; Fisher, E.; Guston, D. A framework for responsible innovation. In *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*; Owen, R., Bessant, J., Heintz, M., Eds.; John Wiley and Sons, Ltd.: Chichester, UK, 2013; pp. 27–50.

4. Van de Poel, I.; Sand, M. Varieties of responsibility: Two problems of responsible innovation. *Synthese* **2018**,195, 1–19.

5. Dreyer, M.; Chefneux, L.; Goldberg, A.; von Heimburg, J.; Patrignani, N.; Schofield, M.; Shilling, C. Responsible Innovation: A Complementary View from Industry with Proposals for Bridging Different Perspectives. *Sustainability* **2017**, 9, 1719.

6. Pellé, S.; Reber, B. Responsible innovation in the light of moral responsibility. *J. Chain Netw. Sci.* **2015**, 15, 107–117.

7. Timmermans, J.; Yaghmaei, E.; Stahl, B.C.; Brem, A. Research and innovation processes revisited: Networked responsibility in industry. *Sustain. Account. Manag. Policy J*. **2017**, 8, 307–334.

8. Zwart, H.; Landeweerd, L.; Van Rooij, A. Adapt or perish? Assessing the recent shift in the European research funding arena from 'ELSA' to 'RRI'. *Life Sci. Soc. Policy* **2014**, 10, 11.

9. Chatfield, K.; Iatridis, K.; Stahl, B.C.; Paspallis, N. Innovating Responsibly in ICT for Ageing: Drivers, Obstacles and Implementation. *Sustainability* **2017**, 9, 971.

10. Stahl, B.C. Responsible research and innovation. The role of privacy in an emerging framework. *Sci. Public Policy* **2013**, 40, 708–716.

11. Stahl, B.C.; Obach, M.; Yaghmaei, E.; Ikonen, V.; Chatfield, K.; Brem, A. The Responsible Research and Innovation (RRI) Maturity Model: Linking Theory and Practice. *Sustainability* **2017**, 9, 1036.

12. Pellizzoni, L. Responsibility and Environmental Governance. *Environ. Politics* **2004**, 13, 521–565.

13. Blok, V.; Lemmens, P. The Emerging Concept of Responsible Innovation. Three Reasons Why It Is Questionable and Calls for a Radical Transformation of the Concept of Innovation. In *Responsible Innovation 2: Concepts, Approaches, and Applications*; Koops, B.-J., Osterlaken, I., Romijn, H., Swierstra, T., van den Hoven, J., Eds.; Springer: Cham, Switzerland, 2015; Volume 2, pp. 19–35.

14. Noorman, M.; Swierstra, T.; Zandbergen, D. Questioning the normative core of RI: The challenges posed to stakeholder engagement in corporate setting. In *Responsible Innovation 3: A European Agenda?* Asveld, L., van Dam-Mieras, R., Swierstra, T., Lavrijssen, S., Linse, K., van den Hoven, J., Eds.; Springer: Dordrecht, the Netherlands, 2017; pp. 231–249.

15. Nielsen, M.V. The concept of responsiveness in the governance of research and innovation. *Sci. Public Policy* **2016**, 43, 831–839.

16. Weiss, R.S. *Learning from Strangers: The Art and Method of Qualitative Research*; The Free Press: New York, NY, USA, 1994.

17. The PRISMA Responsible R&I Toolkit. Available online: http://www.rri-prisma.eu/rri-tool/embedded-ethicist (accessed on 5 October 2019).

18. Blok, V.; Tempels, T.; Pietersma, E.; Jansen, L. Exploring Ethical Decision Making in Responsible Innovation: The Case of Innovations for Healthy Food. In *Responsible Innovation 3: A European Agenda*? Asveld, L., van Dam-Mieras, R., Swierstra, T., Lavrijssen, S., Linse, K., van den Hoven, J., Eds.; Springer: Dordrecht, The Netherlands, 2017; pp. 231–249.

19. Von Schomberg, R. A vision of responsible innovation. In *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*; Owen, R., Bessant, J., Heintz, M., Eds.; John Wiley and Sons, Ltd.: Chichester, UK, 2013; pp. 51–74.

20. Blok, V.; Hoffmans, L.; Wubben, E.F. Stakeholder engagement for responsible innovation. *J. Chain Netw. Sci.* **2015**, 15, 147–164.

21. Asveld, L.; Stemerding, D. Social learning in the bioeconomy: The Ecover case. In Experimentation Beyond the Laboratory: New Perspectives on Technology in Society; van de Poel, I., Asveld, L., Mehos, D.C., Eds.; Routledge: London, UK, 2017; pp. 103–124.

22. Sonck, M.; Asveld, L.; Landeweerd, L.; Osseweijer, P. Creative tensions: Mutual responsiveness adapted to private sector research and development. *Life Sci. Soc. Policy* **2017**, 13, 14.

23. Flipse, S.M.; van der Sanden, M.C.A.; Osseweijer, P. Midstream Modulation in Biotechnology Industry: Redefining What is 'Part of the Job' of Researchers in Industry. *Sci. Eng. Ethics* **2013**, 19, 1141–1164.

24. Long, T.B.; Blok, V. Integrating the management of socio-ethical factors into industry innovation: Towards a concept of Open Innovation 2.0. *Int. Food Agribus. Manag. Rev*. **2018**, 21, 463–486.

Chapter 3

A meta-responsibility outlook on evolving value chains of bio-based innovations

This chapter has been submitted as:

Sonck, M., Asveld, L. A meta-responsibility outlook on evolving value chains of bio-based innovations.

3.1. Introduction

Industrially manufactured materials pass through many hands throughout their life cycle: during product design, manufacturing, distribution, consumption, and final disposal or reutilization. This suggests there are various subjects who are, or can be held to be, responsible for a product, its production, usage, and expected benefits or unintentional impacts. These responsibilities, even when seemingly individual, have a networked character (Timmermans, et al., 2017).

Besides delivering targeted benefits to investors and society, industrial activity, like any large-scale activity, can bring about unintended and undesirable side effects to society and the natural environment. Adverse impacts from production, such as those on climate, food security or biodiversity, remain inadequately addressed in current value chains. Often negative effects appear to result from collective action rather than being attributable to single actors – which is sometimes referred to as the 'problem of many hands' (van de Poel, et al., 2012; Thompson, 1980) – and their impacts extend far beyond single actors and locations (Ceicyte & Petraite, 2018). This drawback is exacerbated by the highly dispersed nature of today's industrial manufacturing. Production largely takes place in fragmented networks involving multiple actors that are often geographically scattered (Ha-Brookshire, 2017; Alexander, 2020). This implies there are few joint arenas for interaction or mutually binding commitments, and therefore, little joint consideration for unintentional impacts either. Responsibility for unintentional side effects remains largely the responsibility of no one.

Addressing the 'problem of many hands' requires us to grasp how responsibilities – understood as various duties, expectations and obligations regarding production, products, and their impacts – become acknowledged and allocated in value chains among participants. The identification of obstacles and enablers of functioning responsibility networks permits finding solutions towards a more just and effective allocation of responsibilities.

One way to study the allocation of responsibilities is to investigate value chains currently under formation. Industrial research and innovation (R&I) not only introduces new products and technologies to the market, but also involves reformulation of value chains. This becomes pronounced when innovations set off broader system-level changes

vis-à-vis existing modes of production, such as in the case of *bioeconomic* and *biocircular* innovations. Bioeconomy brings about a transition from a petrochemical-based production system to a biomass-based one, while circular economy implies transitioning from linear production systems (take-make-waste) to closed-loop systems designed to minimize waste and to maintain products and materials in use as long as possible (Kallergi & Asveld, 2021; Ghisellini, et al., 2016). If applied on a large, global scale, bio-based production would imply a substantial rearrangement of roles, responsibilities, and dependencies among pre-existing and novel value chain actors (Asveld & Stemerding, 2017). In addition to targeted benefits, bio-based production also brings new environmental, economic and social complexities and uncertainties. Especially the social dimension of sustainability is only scarcely considered in the design of novel bioeconomic and circular processes, production facilities, and material cycles (Palmeros Parada, et al., 2018; Murray, et al., 2017).

As a prerequisite, we argue that a systematic approach to the concept of responsibility is required; one which makes a distinction between its different aspects and understandings. The term responsibility encompasses many meanings, for instance referring simultaneously to economic, legal-contractual, and moral responsibilities (Pellé & Reber, 2015). Responsibility can refer to duties linked to specific professional roles, for example those of corporate personnel, or to more broadly shared virtues such as care for future generations (van de Poel & Sand, 2018). Without being explicit, different modalities of responsibility may remain indistinguishable. At worst, this can increase "collective irresponsibility" and contribute to the diffusion of responsibilities rather than alleviate the problem of many hands (Blok & Lemmens, 2015; Zwart, et al., 2014).

Here, the approach of Responsible Research and Innovation (RRI, or RI) provides a point of departure. We look to an idea by Stahl (2013) that RRI can best contribute to innovation management as a *meta-responsibility* approach: by mapping responsibilities that R&I actors hold in society and by supporting their alignment. According to Stahl (2013, p. 708), meta-responsibility involves:

> *"A higher-level responsibility or meta-responsibility that aims to shape, maintain, develop, coordinate, and align existing and novel research and innovation-related processes, actors, and responsibilities, with a view to ensuring desirable and acceptable research outcomes."*

In this paper, we employ meta-responsibility mapping (Sonck, et al., 2020) to explore the allocation of responsibilities in bioeconomic and biocircular value chains under formation. Meta-responsibility mapping is an approach to innovation management which identifies responsibilities and seeks to align those in decision-making under the high uncertainty characteristic to R&I. It involves the inventorying of different notions of responsibility, based on Pellizzoni's (2004) framework, which divides responsibility into elements of *care*, *liability*, *accountability*, and *responsiveness*. By case-studying two bio-based industrial R&I projects with meta-responsibility mapping, our target is to pinpoint barriers and enablers of responsibility allocation between value chain actors. Our research question is: How to apply the vision of responsibility in emerging value chains?

The paper unfolds as follows: Section 3.2 reviews the extant RRI literature on responsibility networks in R&I and, based on this review, adjusts the approach of meta-responsibility mapping to be applicable in multi-actor R&I contexts. The case studies and study methodology are explicated in Section 3.3, while Section 3.4 presents the results and discusses implications. Section 3.4.1 presents four recurrent critical limitations related to the distribution of responsibilities between R&I practitioners and their collaborators. Section 3.4.2 explores these limitations in a more detail, discusses the implications they have on value chain formation, and presents identified practices to cope with them. Finally, conclusions and limitations of the study are presented in Section 3.5.

3.2. Theory: A framework for analysing networked responsibilities

For its theoretical basis, this study builds on earlier RRI literature concerning responsible innovation in multi-actor industrial R&I contexts.

At the core of RRI is a vision of responsible innovation as a process of aligning innovation with societal values, needs and expectations (Rome Declaration, 2014). RRI establishes a link between corporate R&I and corporate responsibility, by pointing to a specific role that R&I units in companies should take in terms of responsibility. During the innovation process, R&I teams and units should steer innovation towards societally acceptable and desirable outcomes, along with securing economic viability. To achieve this, innovators must anticipate implications of their innovation on society and the natural environment and constantly reflect their goals and initial assumptions in light of emerging knowledge. In response, they must make modifications to the properties and pathway of their innovation towards greater societal embeddedness (Stilgoe, et al., 2013). The early

identification of the effects on users and wider society aims at steering the innovation before its trajectory becomes irreversible, or adjustable only at remarkable cost and delay (van de Poel, et al., 2017).

From the outset, the RRI community has called for practices on how to achieve these targets in multi-actor R&I settings. Initially, this was by positing that innovators and stakeholders have a *co-responsibility* for the repercussions of R&I, in terms of jointly defining societally desirable outcomes (von Schomberg, 2013). In other words, actors across innovation ecosystems should undertake shared responsibility for the innovation, at least in terms of jointly considering its broader implications (Owen, et al., 2013; Stilgoe, et al., 2013).

These calls have been responded to by an increasing number of academics from the field of Science and Technology Studies as well as ethics, investigating under the RRI label what the obligation of shared responsibility implies in practical R&I. In the context of our study, we highlight two related lines of research in the RRI literature. The first involves case-studying companies active in R&I, concluding that in this context, the concept of shared responsibility appears highly problematic, and hence, there is little actual practice of sharing responsibility for R&I processes and products (Blok & Lemmens, 2015; Blok, et al., 2017; Noorman, et al., 2017; Sonck, et al., 2017).

Blok and Lemmens (2015) first argued that the idea of co-responsibility is both naive and unrealistic in terms of corporate reality: Innovation is the primary source of competitive advantage for companies; implying that the sharing of knowledge, resources and capacities is restricted between companies and their stakeholders. Second, as innovations are risky and costly, there appears agreement between investing companies and their stakeholders that the investor alone is responsible for the risk-reward assessment and therefore the investment decision (Blok & Lemmens, 2015).

While fully acknowledging the validity of the above findings, we take another viewpoint to the problematic appearance of co-responsibility in RRI, by arguing that it is one ramification of RRI's broader deficiency in delivering a proper definition for its core term of *responsibility*. In this respect, we spotlight another stream of RRI literature. Pellé and Reber (2015), Dreyer et al. (2017), and Timmermans et al. (2017) have remarked that the absence of a systematic framework of responsibility has greatly hampered RRI's theoretical credibility as well as practical relevance. The vagueness about what

responsibility entails and requires has left RRI impotent in terms of providing support for the management of responsibilities. In multi-actor settings, the diffusion of different aspects of responsibility, at worst, reinforces the problem of many hands rather than dissolves it (Zwart, et al., 2014). Regarding co-responsibility, it can remain overlooked that while some aspects of responsibility remain strictly non-shareable (e.g., professional duties), others could have collective displays (e.g., moral responsibilities).

To make RRI more explicit and detailed concerning responsibility, Stahl suggested - already in (2013) - to develop RRI into a *meta-responsibility* approach equipped to inventory and coordinate actors and their responsibilities in R&I networks. To date, some studies have answered this call. Referencing meta-responsibility, Chatfield et al. (2017), Timmermans et al. (2017), Ceicyte and Petraite (2018), Sonck et al. (2020) and Ceicyte et al. (2021) have studied the formation and management of responsibilities and responsibility networks in corporate R&I. This stream of literature provides an academic point of departure for our study. To answer our research question, we adopted two methodological approaches from the literature: a framework for distinguishing different elements of responsibility and the mapping of actors in R&I networks.

3.2.1. Responsibility framework for distinguishing between different elements of responsibility

To study the allocation of responsibilities, a framework is first required that explicates *in what sense* the identified actors in evolving value chains are – or can be reasonably held – responsible for the outcomes of prospective industrial production.

Sonck et al. (2020) and Ceicyte et al. (2021) earlier employed such a framework in the context of industrial R&I. Ceicyte et al. (2021) applied a framework dividing responsibility into a *legal* element (based on laws and jurisprudence), a *contractual* element (mutual obligations set in agreements), and a *moral* element (based on norms embedded in value systems and cultural context). Surveying the R&I activities of companies in several industrial sectors, the authors reported the co-existence of these responsibility elements and identified practices with which companies implemented them. The authors noted that while RRI tends to focus on moral responsibilities, legal and contractual responsibilities are also essential in industry for implementing responsible innovation.

Case-studying a bioeconomic R&I project, Sonck et al. (2020) applied the division of responsibility into elements of *care*, *liability*, *accountability,* and *responsiveness*. Initially introduced by Pellizzoni (2004), in the context of environmental governance, this framework was further elaborated on by the authors to become more attentive to the uncertainty of R&I (Figure 3.1). Like Ceicyte et al. (2021), the authors found that responsibility elements coexist in the goals, motivations, concerns and working methods of R&I personnel. Rather than simplified mindsets, elements became distinguishable in relation to one another - for instance, as conflicting viewpoints in difficult decision-making situations.

The framework in Fig. 3.1 sets out by describing two challenges characteristic to R&I and presents the responsibility elements as distinctive mindsets in addressing these challenges.

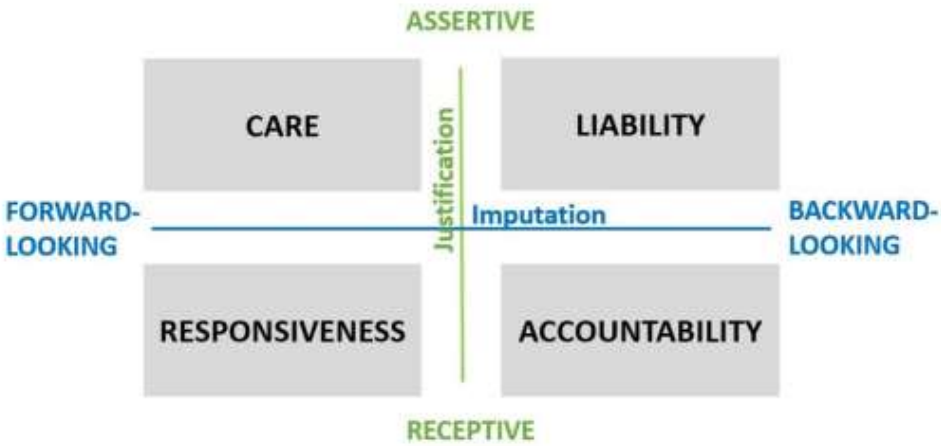

Figure 3.1. A framework presenting the elements of responsibility, based on Pellizzoni (2004) and modified into the R&I context by Sonck et al. (2020).

The first challenge is that our ability to foresee consequences of innovation, being a future-oriented activity, is severely limited. Even the meaning of what is a 'good' or 'desirable' outcome can change over time, for instance with changes in consumer demand and societal values (Pellé & Reber, 2015; Sonck, et al., 2020; van de Poel & Sand, 2018). Two stances can be taken on how to **justify** actions under these circumstances. A *receptive*

stance acknowledges uncertainty about the impacts of R&I, and weighs options based on one's best available knowledge at the time (accountability), or, through 'learning-by-doing': constantly re-adjusting targets while working with the innovation (responsiveness). In an *assertive* stance, it is known beforehand what is right and what is wrong – or it is believed to be known – in light of legal and contractual canons (liability) or moral codes and norms (care).

Second, it can be very challenging to **impute** the consequences of innovation back to their originators: to establish a cause-consequence relation of "who did what" between an individual actor and consequences of said actions. In R&I, two mindsets can be taken with this respect. A *forward-looking* mindset (care and responsiveness) embraces the opportunity to improve the current state-of-affairs through innovation, placing less emphasis on who to blame (or praise) for the failure (or success) of trying this. On the other hand, a *backward-looking* mindset (liability and accountability) is driven by the expectation that possible harms (or benefits) will eventually be assessed and hence more precaution taken, as well as attempts to understand the impacts before acting (Pellé & Reber, 2015; Sonck, et al., 2020; van de Poel & Sand, 2018).

To address the problem of many hands in emerging value chains, we highlight the importance of making the above distinction between responsibility elements. Regarding justification: the distinction between receptive and assertive elements is necessary for conceding that innovation, as a future-oriented activity, is inherently uncertain and its impacts cannot be fully anticipated. Along with assertive normative and legal-regulatory guidelines, receptive management strategies are needed in R&I to deal with residual uncertainties that cannot be exhaustively eliminated nor identified before the innovation is introduced in society (van de Poel, et al., 2017; Sonck, et al., 2020). For instance, prototyping and piloting are established strategies in industrial R&I to gradually extend knowledge and make needed adjustments iteratively, before a decision about full production scale is made (Asveld & Stemerding, 2017; Lubberink, et al., 2017).

Regarding imputation: it needs to be acknowledged that indirect societal impacts from innovation often result from highly complex and far-reaching cause-consequence relations and pinpointing responsibilities for these is notoriously difficult (van de Poel & Sand, 2018). It is important to see a difference between unavoidable causal complexity and those structures or conventions that further complicate and diffuse the attribution of responsibilities at an organizational or inter-organizational level – some of which can be

impacted. When causal connections are reasonably distinguishable, foreseeable and demonstratable, it may be feasible to establish accountability for such impacts. In an event of high complexity, promoting a forward-looking "collective stewardship" can be a more justifiable option (van de Poel & Sand, 2018; Stilgoe, et al., 2013). For instance, R&I partnership agreements are convenient and highly useful when clarifying task coordination and attribution of accountability or liability for events that are causally obvious (assessable, imputable). Yet, overcoming challenges of a more unforeseeable and complex nature may demand collective responsiveness, such as ad-hoc problem solving amongst R&I partners, or shared goals that set directions towards societally beneficial outcomes (care, e.g., sustainability goals).

3.2.2. Mapping the actors and objects of responsibility in emerging value chains

Responsibility can be understood as a relationship and, according to this characterization, it is fundamentally networked (Timmermans, et al., 2017). To grasp *who,* in a multi-actor value chain, is responsible *to whom* and *for what*, the actors of the value chain need to first be inventoried. Case studies by Timmermans et al. (2017), Ceicyte and Petraite (2018), and Ceicyte et al. (2021), focusing on the formation of responsibility networks in multi-actor R&I, have earlier inventoried actors and objectives of R&I and explored the interdependencies between them.

A functioning responsibility relationship involves a **subject,** as someone or something that is responsible, and an **object,** as someone or something that the subject is responsible for (Stahl, 2013; Timmermans et al., 2017; Ceicyte et al., 2021). The link between the subject and the object is often supported by an **authority** overseeing the responsibilities and attributing sanctions to the subject. In addition to authorities, also **norms** influence a subject's actions, as prescriptive criteria to which the subject must accord to (Stahl. 2013; Timmermans et al., 2017; Ceicyte & Petraite, 2018). Given the entangled nature of responsibility networks, responsibilities are not allocated entirely unambiguously: for instance, the same actor can have multiple simultaneous roles as subject, authority, and object (Timmermans, et al., 2017).

Adding to the above literature, we argue that not only authorities and norms, but also the **capacity** to assume responsibility sets conditions for actors to act as subjects of responsibility. When mapping responsibilities, capacity should be noted as well. From an

ethical point of view, an actor in a value chain not only needs to recognize a moral issue or a societal norm as it relates to innovation, but also establish a moral intent and eventually act accordingly (Blok, et al., 2017; Jones, 1991). In other words, value chain actors differ in *response-ability* as to what extent they are capable of influencing the shape of innovation – and how well informed and equipped they are when voicing their wills or concerns (Felt, 2017; Blok & Lemmens, 2015). The disparity of *response-ability* between actors is highlighted in the business realm, in the sense that information asymmetries are intentionally sought out via innovation to secure competitiveness (Blok & Lemmens, 2015).

3.3. Case projects and research methodology

Two case studies form the empirical backbone of this paper: one on bioeconomic innovations (the Bio2X project) and another from the field of circular economy (the Biocomposite consortium, i.e., the BC consortium). Bio2X is the principal case for this study, in the sense that primary data, gathered by interviewing Bio2X members, was analysed utilizing systematic qualitative methods for the purpose of this paper. While Bio2X was initially presented in Sonck et al. (2020), the findings reported in the present paper provide an original contribution by focusing on relations between Bio2X and its collaborators, expanding the earlier scope in Sonck et al. (2020) that focused on decision making at R&I team level. The BC case study acts in a supportive role, and is reported in full in Kallergi and Asveld (2021). While primary data of BC is not available due to reasons of confidentiality, the extensive report by Kallergi and Asveld (2021) and its findings provide complementary insights into our research question.

3.3.1. Bioeconomic case study: Bio2X

As initially presented in Sonck et al. (2020): Bio2X is an R&I project within Fortum – a large-size enterprise headquartered in Finland. At the time of the case study, Bio2X was developing a biorefinery concept to convert lignocellulosic biomasses, namely wood and agricultural straw residues, into their structural components (i.e., fractions) by employing conversion technologies referred to as fractionation technologies. These fractions – cellulose, hemicellulose, and lignin – would then be further manufactured into various bio-based products in commercial partnerships with industrial manufacturers and consumer brand owners. In the so-called 'upstream' part of the project, the team evaluated different fractionation technology options in collaboration with start-up companies developing those technologies, and upscaled selected technologies towards the pilot-scale to get proof

of technical feasibility. In the 'downstream' part, the aim was to establish a demand for the produced bio-fractions among manufacturing industries. The team members networked with manufacturers of e.g., textile, construction, and cosmetics sectors, who were testing applicability of Bio2X's fractions as ingredients for industrial and consumer applications.

At the time of the study, the project was at a relatively early stage. In terms of typical innovation stages (Dreyer, et al., 2017), the project was, to a major extent, at the exploration stage (applied research) and to lesser extent at the development stage (pilot and demonstration), while the implementation stage (delivering value to consumers and society) was still years in the future. The early stage in R&I implies a high uncertainty regarding the project's outcome (van de Poel, et al., 2017; Blok & Lemmens, 2015). For instance, Bio2X personnel was managing a considerable number of open product and technology options, among which they were experimenting to find the most technically and economically feasible alternatives. Feedstock options of wood and agricultural straw residues were also under evaluation at the time of case studying (straw was eventually chosen). Furthermore, biorefining experiments were mostly on a small pilot scale which is only limitedly representative for eventual large-scale biorefining.

While comparing different feedstock, product, and technology options, the Bio2X team was also shaping the contours of future bio-based value chains. Figure 3.2 presents a generalisation of a bio-based value chain. It illustrates, firstly, that bio-based manufacturing involves several stages: raw material acquisition, separation and refining of bio-based fractions, multi-step processing into product intermediates by industrial partners, formulation into final products by e.g., consumer brand-owners, and eventually, usage and post-usage stages. Bio2X interacted simultaneously with several potential partners and clients. At the time of the interviews, most of the direct ongoing interaction was with fractionation technology providers, the intermediate producers next-in-line with Bio2X in the value chain, and to some extent with the final product manufactures and brand owners. At the time of the case study, there was little direct interaction with those at the extremities of the value chain: i.e., the feedstock suppliers and end-product users. Finally, it should be noted that there were many stakeholders not taking part in the material conversion but nevertheless had the capacity to influence the project (or be impacted by it). These included stakeholders specific to the R&I phase (e.g., R&I institutes, external research funders), internal stakeholders within Fortum, governmental and municipal officials, and non-governmental actors.

3.3.2. Bio-circular case study: BC consortium

Kallergi and Asveld (2021) case-studied a development project of a novel biocomposite, referred to as 'BC'. BC was produced using ingredients recovered during wastewater treatment: a novel biopolymer excreted by micro-organisms used in specific wastewater treatment technology and cellulose fibres from sieved toilet paper. The project was instigated by a consortium of academic and industrial partners active in the fields of wastewater treatment, novel biomaterial research, post-treatment of wastewater (sourcing of the biopolymer), biocomposite production, and the construction industry (Fig. 3.2). In addition, the project's wider stakeholder community included an owner and operator of wastewater treatment technology. The project and the formation of the consortium were driven by the emerging trend of resource recovery from wastewater treatment sources; to extract high-value products from wastewater as an alternative to virgin materials. As such, BC is one manifestation of a circular economy and exemplifies a bio-circular value chain (Fig. 3.2). BC was envisioned to be a fully bio-based, circular, and biodegradable alternative to current composites in the construction and infrastructure sectors. Its development work was at a mid-phase stage (or "development stage", (Dreyer, et al., 2017)), with the exact recipe and production process of BC then being under development. Like Bio2X, the development of BC involved a "partially established, multi-actor value chain" (Kallergi & Asveld, 2021, p. 2) coping with considerable uncertainty regarding the outcome of the innovation. The uncertainty in BC derived largely from the complexity and variability of wastewater feedstock and related to this feedstock, possible health and safety risks during the production and usage of BC.

As its research question, the BC case study queried on what risks can be identified with BC and to what extent those risks can be addressed at the R&I stage through product and technology design actions. The study methodology included interviews, participation in consortium meetings, and a focus group study on public perceptions of BC conducted with representatives of prospective end users of BC. The focus group study is reported in de Winter (2021). In particular, these questions examined the applicability of Safe-by-Design in a circular economy context. Safe-by-Design is an approach to risk management, through which innovation practitioners can anticipate risks of new products and technologies at an early stage of their development and then make safety-motivated choices in the product's properties and design (Kallergi & Asveld, 2021). While the study's focus was on Safe-by-Design, the authors also called for additional approaches supporting

task coordination and responsibility allocation in bio-based and circular value chains. Our answer to this call comes through exploring the BC study findings utilizing a meta-responsibility framework; providing complementary insights into the challenges related to value chain formation.

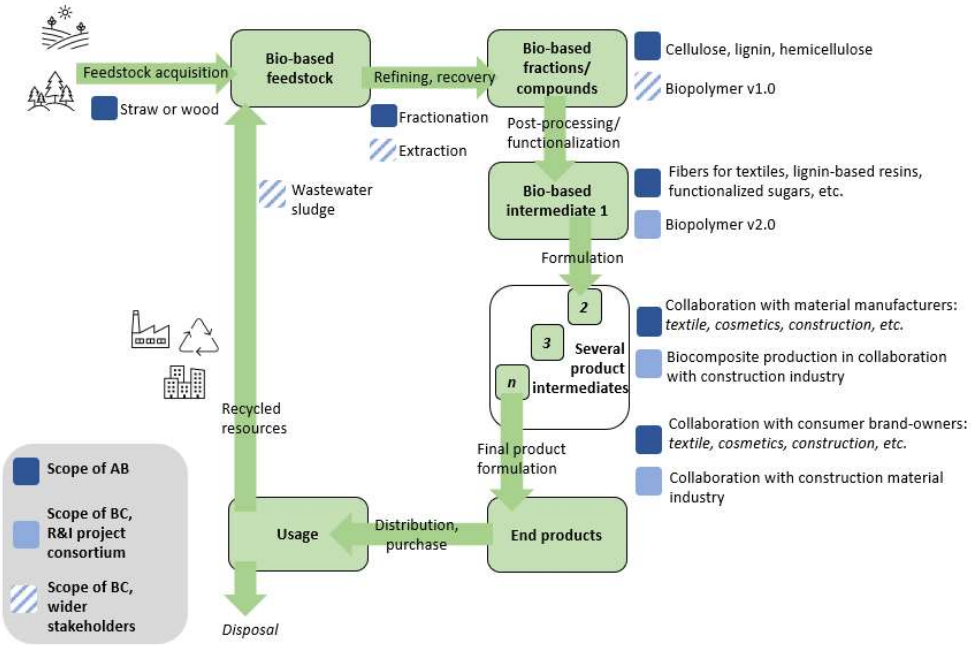

Figure 3.2. A generalized bio-based value chain diagram based on the Bio2X and BC cases, in which bio-based materials, transferring from one manufacturer to the next, become increasingly processed towards end products. The areas where Bio2X and the BC consortium had active development during the case studying are marked with dark blue and light blue, respectively. In addition, for BC: the striped light-blue marking represent areas that were outside the scope of the BC consortium, but in which their wider stakeholder community had ongoing R&I activity.

3.3.3. Combining the two case studies

Several reasons supported combining the Bio2X and BC case studies for the purpose of this paper:

First, the cases bear thematical similarities, suggesting that their findings have mutual relevance. Both bio- and circular economic value chains are typically long, involving several steps and actors processing the raw material via intermediary products until the final product emerges. Both bring about system-level changes vis-à-vis the existing modes of production, and in both, transforming feedstocks into bio-based ones introduce new uncertainties related to material sourcing and utilization (e.g., health, sustainability). Second: regarding the degree of industrial maturity - both bioeconomic and bio-circular production are still relatively novel production modes. Many of their targeted applications are at a pre-commercial development stage and value chains are still incomplete, implying considerable uncertainty regarding the success of R&I projects.

Third, in questions where the data coverage of the primary Bio2X case study was scarce, looking at another case study offered a way forward. Fourth, and related: rather than rely on a single case, two case studies were employed to enhance the validity and generalizability of the findings. Fifth, combining the findings from two case projects allowed us to present a broader spectrum of foreseeable solutions and management practices, which in turn, may serve as the basis for further studies.

Finally, there were practical reasons behind the case study selections. Regarding accessibility of data, the lead author of the present paper was employed at Bio2X at the time of the case study, having been granted permission to conduct data gathering and analysis and having access to the primary data. The second writer of this paper was also a co-author of the BC consortium study, having access to its primary data. Hence, second-hand insights from both cases were cross-checked through discussion between the authors, providing a strategy of validation when formulating conclusions.

3.3.4. Materials and methods

As reported in Sonck et al. (2020): The primary data was gathered through semi-structured interviews conducted in Bio2X over a period of 4 months in 2018. The interview questions were grouped into five sets (the questionnaire is available by request from the lead author). In the first set, respondents were asked to describe Bio2X, what elements in the project motivated them, and what their main concerns regarding the project's outcomes were. Second, the interviewees were asked how they understood corporate responsibility and what wider societal and environmental impacts the respondents envisioned would result from the project – both positive and negative. Third, the

interviewees were asked to describe the current stage of the project and what it was like to make decisions at that stage. Fourth, it was queried as to what extent wider societal and environmental impacts were taken into consideration in the decision-making process. Finally, respondents were asked about Bio2X's stakeholders and the ways of working with them.

There were 13 interviewees in total. To gain a diverse perspective on the project, the interview group was comprised of 7 team members (project managers, technology experts, and trainees), 4 external consultants working for the project (3 with business and marketing background and 1 with an academic background), and 2 internal stakeholders from other units of the company (1 sustainability expert and 1 from upper management).

The interviews were recorded, and the recordings were translated and transcribed into English. The transcripts were coded using the MAXQDA coding tool, the first coding round identifying *subjects, objects, authorities, and norms* in the transcripts. The second coding round was conducted for identifying the elements of *care*, *liability*, *accountability,* and *responsiveness* (Fig. 3.1) in relations between the actors and objects identified in the first coding round.

While studying the coded data, we recognized that the notion of *capacity* (or response-ability) of subjects to undertake responsibilities was truly helpful in interpreting occasions where the identification of either actors or their responsibilities were difficult. Accordingly, we applied the concept of capacity to further categorize our findings.

Next, the BC case study report (Kallergi & Asveld, 2021) was analysed using Fig. 3.1, to identify responsibility elements at stake in the relations between the BC consortium actors and the biocomposite under development. Finally, we mirrored these findings against those of Bio2X: uncovering to what extent they were complementary and mutually supportive, and whether any major disparities appeared between the studies.

3.4. Results and discussion

The first key finding from analysis of the data is a tendency towards clearly defined *accountabilities*. Bio2X respondents underscored that biomaterial, whenever delivered to or sent from Bio2X, needed to fulfil targeted quality specifications, and they strived to keep clear and traceable who was responsible for delivering which material property. In line with

van de Poel and Sand (2018), accountability facilitates the formation of value chains as it establishes and sustains causal connections between subjects (the material suppliers) and the outcomes of their actions (material quality), and further, defines conditions for the transfer of material ownership downstream (acceptable material quality). Keeping precise records as to what is supplied to whom, and whenever materials cross organisational boundaries, can be construed as one strategy against the 'problem of many hands'.

The flow chart of Figure 3.3 presents a caption of the emerging value chain in Bio2X's vicinity, illustrating how accountability for biomaterial transfers from one supplier to the next as material moves downstream in the value chain.

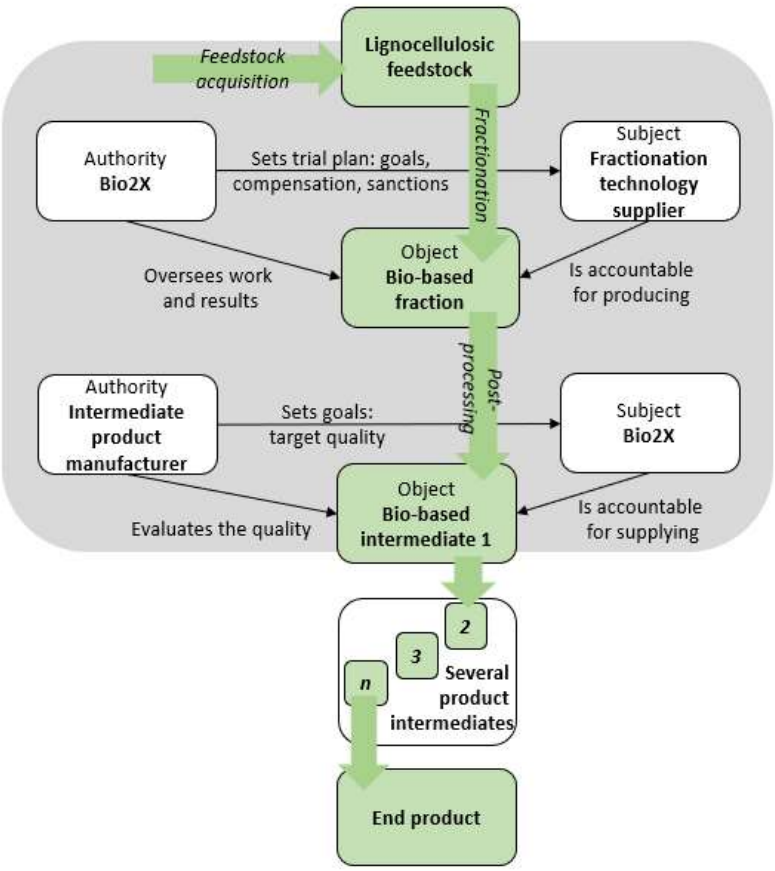

Figure 3.3. Responsibility network in the Bio2X case. The grey background indicates the part of value chain in Bio2X's vicinity, in which accountabilities were clearly recognizable in the case study.

In this exemplary diagram, Bio2X represents a future biorefinery operator (*authority*) commissioning pilot trials from a fractionation technology provider (*accountable subject*) to produce cellulose, lignin, and hemicellulose fractions with targeted properties (*object*) as proof-of-concept for technological viability. In line with earlier findings by Timmermans (2017), individual actors can have multiple roles in a value chain. Moving one step downstream in Fig. 3.3, the fraction samples (*object*) are further processed to be tested by industrial manufacturers – the potential future clients of the biorefinery. The industrial manufacturer now stands as an *authority* by setting the target quality for the samples (*object*), while Bio2X is the *accountable subject* supplying samples to the manufacturer according to the target quality.

As a responsibility classified as 'backward-looking', accountability is established on well-defined and measurable objects, e.g., cellulose with a specific fibre length, evaluated by the material receiver (authority) providing feedback about the fraction quality. In Bio2X, accountabilities were often further enforced on a contractual level, bringing in the aspect of *liability* into collaborations. Project plans, purchasing conditions, and non-disclosure agreements (NDAs) set sanctions for breaching agreements as well as established principles for sharing the benefits of collaboration, such as foreground intellectual property rights.

However, in several ways, the Bio2X and BC cases illustrate that accountability can only be clearly assigned among actors that are close to one another in the value chain. When interviewees referred to events taking place further down- or upstream in the value chain or to broader impacts beyond the immediate value chain, distinguishing roles and responsibilities became less straightforward. We discovered that the capacity (or response-ability) of actors to assume accountability (or expect it from others) is in many ways limited. It would appear unrealistic to attempt to plot a complete overview of a distribution of accountabilities among actors which covers an entire production cycle from raw material to final product.

In combining the findings from Bio2X and BC, four critical reasons stood out that complicate allocation of responsibilities in bio-based value chains concerning these occasions of limited capacity. The first limitation is related to the sheer number of industrial actors involved in material processing, often 'blending together' elements from different materials sources. It becomes overly complicated to determine who is accountable for the overall properties and impacts of multi-ingredient products. Second: No explicit authority

appears who would demand accountability for the less immediate, wider, and indirect impacts of biorefining. Third**:** Seemingly shared normative goals (e.g., safety, sustainability) can become understood and prioritized differently among value chain participants. This may lead to blind spots and misunderstandings in the value chains. Fourth*:* The normative basis institutionalized by authorities, such as environmental or safety regulators, may be inconsistent with the opportunities and risks introduced by novel materials, thus favoring established value chains.

Using value chain visualization, these critical limitations are illustrated in Figure 3.4.

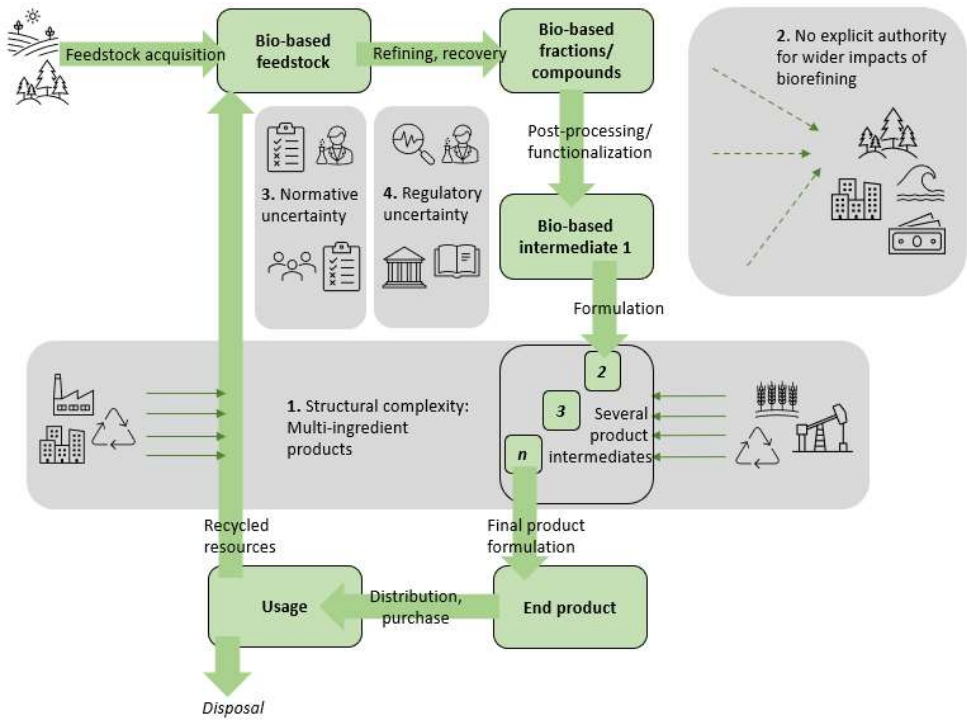

Figure 3.4. Visualization of critical limitations that complicate allocation of accountabilities in bio-based value chains.

Table 3.1 summarizes critical limitations using the terminology of meta-responsibility and describes implications at the level of individual R&I projects, as well as broader value-chain level repercussions.

Table 3.1. Critical reasons for limited accountability in bioeconomic and bio-circular value chains

The setting	Critical limitation in terms of meta-responsibility	R&I-level implications (limited capacity)	Value chain implications (limited capacity)
Multi-ingredient products, blending elements from several sources.	Accountability for impacts becomes diluted among subjects of the value chain.	'Outbound' uncertainty regarding actions further downstream, 'inbound' uncertainty regarding actions upstream.	Structural complexity. No overall responsibility for the overall lifespan of products and materials.
Wider impacts of biorefining: indirect, delayed, spreading afar in society or environment.	Authority imposing and monitoring accountability remains inexplicit, indirect, or unidentifiable.	No explicit, forceful guidance towards addressing wider impacts.	Wider impacts of manufacturing remain largely unaddressed and uncompensated.
Joint goals, such as safety or sustainability: superficially shared yet understood and prioritized differently.	Normative uncertainty: How to transform care for societal impacts into coordinated actions and accountability?	Normative differences between value chain actors remain unnoticed and unresolved at the individual R&I level.	Blind spots and conflicting understandings among value chain actors regarding goals of innovation.
Regulations incomplete in light of risks and opportunities introduced by novel materials and production modes.	Regulatory uncertainty: How to keep regulatory requirements (liabilities) up-to-date and relevant?	Existing standards appear incomplete, inappropriate, and outdated, slowing down R&I.	Existing standards favour established value chains, not capturing all relevant impacts of innovation.

The next sub-sections will discuss the four critical reasons in a more detail, present identified strategies and management practices to overcome them, and discuss the implications of these findings at the value chain level.

3.4.1 Multi-ingredient products: Accountability for output is diluted among subjects

Bio-based and circular value chains involve multiple consecutive manufacturers who apply each other's output materials as feedstock. When moving downstream in the value chain, bio-based ingredients become gradually mixed with other raw materials (often petrochemical) in the product intermediaries, and eventually, the share of individual bio-based components in the end product can be small. This implies 'outbound uncertainty' for Bio2X developers; in terms of a limited capacity to influence the further developments of their fractions. In terms of responsibility, in such value chain structures, it becomes increasingly complicated to keep track of *accountabilities*. Even if an individual material producer would deliver their materials in proper quality and environmental footprint to that next one in line, a diffusion of responsibilities becomes apparent when it comes to accountability for sustaining these features through to the eventual end product. No subject appears to be held accountable for a product's overall life cycle and impacts, such as those related to overall sustainability or safety.

The BC case presents a complementary perspective to the same issue, illustrating an 'inbound uncertainty' derived from the usage of wastewater as an input material. The BC developers had practically no influence on the composition of the wastewater – a complex and partly uncharacterizable material accumulated from various sources. While developers were broadly aware of safety risks related to waste materials, they had very limited influence on actions upstream in the value chain, and thus, most options for mitigating these risks were beyond their control. As a result, BC consortium members typically operated "within their own sphere", exercising only choices readily available to them (Kallergi & Asveld, 2021).

Yet, many interviewees felt that their responsibility somehow reaches through the value chain, hoping to be able to maintain some degree of influence on the downstream developments of their material. BC respondents were concerned about long-term health risks associated with waste-derived materials downstream, while some Bio2X respondents deliberated over whether the targeted final products were ultimately more sustainable than those on markets today. In terms of ethical decision making (Blok, et al., 2017; Jones, 1991), the respondents identified a moral issue – accountability for impacts across the value chain – but it appeared less clear on how to transform this into intention or action.

Table 3.2 gathers identified management practices in BC and Bio2X, for 'extending' responsibility of material developers beyond their immediate outputs and accountabilities. The table makes a distinction between those implementable by individual R&I groups, and those requiring involvement of broader value chain.

Table 3.2. Identified management practices for material developers to undertake responsibility beyond their position in the value chain.

Management practices	**Interpreted with meta-responsibility**
Measures implementable by individual R&I	
Material-specific technical R&I to minimize risks.	Accountability by R&I for its immediate material output.
Impact material properties by choice of feedstock type (e.g., municipal vs. industrial wastewater)	Accountability for what type of R&I input is accepted.
Impact end product options by choosing with whom to partner.	Accountability extended beyond immediate R&I outputs Liability via contractual measures (e.g. ethical partnering criteria).
Material safety data sheet for downstream parties.	Liability for risks related to material usage.
Auditing value chain partners.	Liability via application of monitoring protocols.
Life cycle analyses (LCAs), Preliminary LCAs at early R&I stage.	Accountability, Anticipation of accountability.
Measures requiring involvement of the broader value chain	
Prefer end applications that minimize risks related to usage.	Care about negative impacts at usage (when risks supposedly known before product launch).
Monitor behavior of material after product launch.	Responsiveness to residual uncertainty related to novel materials (either known or unknown risks).
Shared sustainability objectives in R&I consortia.	Care, utilizing joint normative anchor points.
Collective problem-defining and problem-solving in R&I consortia (e.g., inventory of risks and solutions).	Responsiveness, through jointly defining the goals and the means to reach them.

To summarise: There are certain well-established measures by which individual R&I can undertake accountability for proceedings downstream (e.g., partnering criteria), or mediate liability for downstream partners (e.g., material safety data sheets). Yet, as many impacts are the cumulative result of multiple actions, value-chain level solutions are required. Collective actions by industrial R&I consortia, such as setting joint sustainability goals and joint problem solving, exemplify forward-looking responsibility for collective impacts. Yet, an absence of accountability for cumulative impacts points towards a

structural limitation derived from the configuration of material value chains and remains difficult to remedy.

3.4.2. Wider impacts of biorefining: No explicit authority demanding accountability

Besides delivering expected benefits to investors and society, biorefining, like any industrial-scale activity, has broader and indirect repercussions, both positive and negative. These impacts can be difficult (if not impossible) to predict, highlighting the role that R&I teams have in anticipating and frequently reflecting on the impacts of their innovation (Stilgoe, et al., 2013). Moreover, as wider impacts are often collective (van de Poel, et al., 2012), measures are required that go beyond single R&I projects and enterprises, involving the activation of value-chain level drivers.

Bio2X respondents identified various indirect outcomes of biorefining which impact surrounding ecosystems and local livelihoods. The respondents also 'felt responsibility' for these impacts; contributing towards resolving global environmental crises and improving local livelihoods were important personal motivators in their work. To a certain extent, broader impacts were also considered in decision making regarding future biorefinery. For instance, it was decided to utilize lignocellulosic feedstocks to reduce competition with food crops, and further, to focus on the utilization of lignocellulosic residues from agriculture (straws). Moreover, Bio2X examined strategies to avoid soil impoverishment in case straw was utilized on a large scale for biorefining, e.g., looking at ways to circulate nutrients back into the soil. Similar motivations can be traced in the BC case study. To the developers of BC, their investigation was motivated by broader safety and sustainability concerns. For instance, the use of ingredients recovered from waste was discussed as a means to address known controversies surrounding bio-based materials, namely the use of land for growing feedstock crops instead of food. Thus, the BC developers explicitly link their R&I efforts to the broader societal goals of promoting sustainable and circular production.

From the viewpoint of ethical decision making (Blok, et al., 2017; Jones, 1991) a societal issue (food security) was recognized in Bio2X and BC and judged to be problematic, and an intent to act on this was started and eventually implemented in the decision making process. In the data analysis, however, we often noticed an absence of an explicit *authority* who would impose and monitor responsibility for wider impacts. Only in situations where

existing environmental regulations imposed clear liabilities, for instance via an Environmental Impact Assessment as a pre-condition for an operational permit, was an authority clearly recognizable. These findings encouraged taking a closer look at the driving forces behind fulfilling positive societal and environmental impacts in R&I.

Table 3.3 summarizes identified sources of justification in addressing wider impacts, in the absence of an explicit authority.

Table 3.3. Identified practices to establish justification for addressing wider impacts of bio-manufacturing during R&I.

Management practices	**Interpreted with meta-responsibility**
Measures implementable by individual R&I	
Personal values and moral views as motivator in R&I work.	Care, as morally motivated responsibility. 'Self as authority'.
Norms (e.g., related to sustainability) taken to corporate strategy level, guiding R&I in the form of strategic goals.	From morally obligating norms (care) to accountability of fulfilling corporate strategy.
Look for synergies between the business case and wider impacts (e.g., resource efficiency, local livelihoods).	Accountability for establishing new business and care for its wider impacts are in sync.
Anticipate regulatory changes, such as tightening environmental legislation.	Anticipation of changes in current operating environment, of emerging liabilities and authorities (responsiveness).
Measures requiring involvement of the broader value chain	
External funders of R&I (public, private) setting goals for wider impacts (e.g. CO_2 decrease, employment increase)	Funders in authority position impose accountability for fulfilling conditions for funding.
Policymakers broadening the scope of regulation.	Policymakers and regulators as authority, having power to impose liabilities on actors throughout value chain.
Paradigm shift in private sector, regarding value generation for shareholders and stakeholders.	Accountability for creating value for shareholders broadened towards societal stakeholders as well.

In summary: In the absence of an explicit authority that would impose accountability for the wider societal impacts, our analysis pinpointed incentives for addressing those impacts at the R&I level, derived from employee motivations and corporate strategic goals (care and accountability, respectively). At the value chain level, R&I funders and regulatory bodies were identified as the key players with the capacity, as *authority*, to further transform care for society into funding accountability and regulatory

liability, respectively. R&I, to be successful, must also anticipate future changes in the operational environment (responsiveness), such as the tightening of environmental regulations.

3.4.3. Normative and regulatory uncertainty in emerging value chains

The last two limitations which complicate responsibility allocation in emerging value chains are related to the norms guiding activities and decisions. We identified *normative uncertainty* in cases where generally accepted norms, such as 'safety' or 'sustainability', became perceived and prioritized differently among value chain actors. If unnoticed, different interpretations can lead to blind spots or misunderstandings in evolving value chains (Section 3.4.3.1). Further, we recognized *regulatory uncertainty*: The current normative basis institutionalized by regulatory authorities, such as environmental and safety regulations, could not fully grasp the opportunities and risks introduced by novel materials, thus favoring established value chains (Section 3.4.3.2).

In view of the responsibility framework (Fig. 3.1), normative and regulatory uncertainties become explicable as tensions or imbalances between different aspects of responsibility, emerging when novel bio-based materials and processes set off changes in existing value chain structures, roles, and conventions. The *meta-responsibility map* of Figure 3.5 gathers these identified imbalances. For each, we also present a 'guiding question' to support recognition and addressing the responsibilities at stake.

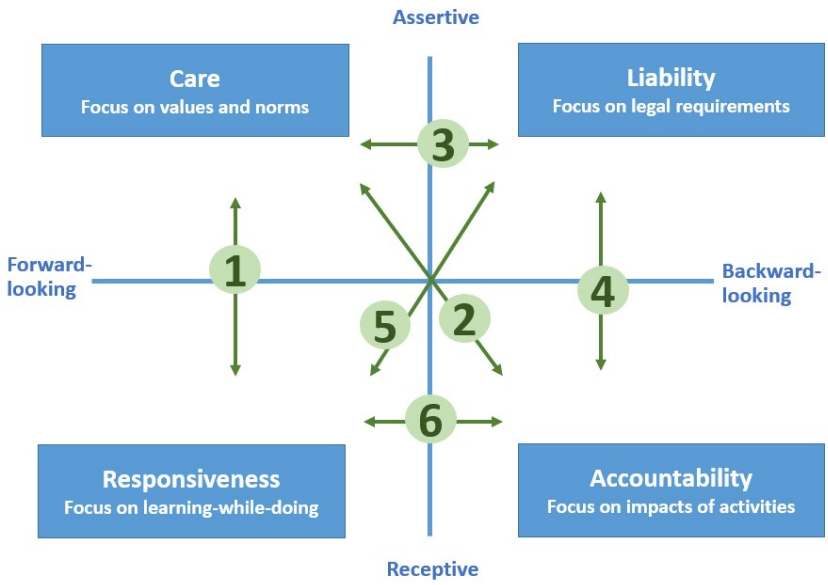

Figure 3.5. A meta-responsibility map for supporting allocation of responsibilities in bio-based value chains. The green arrows indicate the identified tensions and imbalances between different aspects of responsibility. The guiding questions to identify and address these tensions and imbalances are mapped using numbers as identifiers.

The guiding questions numbered in Fig. 3.5 are further explicated in Table 3.4, together with the identified elements of responsibility that the guiding questions target to address:

Table 3.4. Guiding questions with the corresponding responsibility elements at stake, as numbered in Fig. 3.5.

#	Guiding question	Responsibilities at stake
1	Are norms, values and goals similarly understood and prioritized? (Normative uncertainty)	• *Care*, as following normative anchor points • *Responsiveness*, as normative questioning and mutual learning
2	Is one's impact footprint in line with one's values? (Normative uncertainty)	• *Care*, as recognition of values and norms (what one deems important) • *Accountability*, as making an impact (what one really does)
3	Do regulations comply with society's normative basis? (Regulatory uncertainty)	• *Care*: what is generally considered as right or good (societal values and norms) • *Liability*: what do regulations and legislation require
4	Can regulations properly grasp the opportunities and risks of innovation? (Regulatory uncertainty)	• *Liability*, as fulfilling formal requirements (what needs to be proven) • *Accountability*, as knowing the impacts of an activity (what really needs to be understood)
5	Do regulations enable a level playing field for established and emerging activities? (Regulatory uncertainty)	• *Responsiveness*: Appeal to emerging opportunities (for the benefit of novel solutions). • *Liability*: Appeal to compliance with current regulation (in favor of extant licenses to operate)
6	What risks are afforded to take, and where is precaution non-negotiable? (Regulatory uncertainty)	• *Responsiveness*: Innovation principle, address risks with experimentation and learning • *Accountability*: Precautionary principle, stop or eliminate risks before acting

We emphasize that normative and regulatory uncertainty cannot be addressed adequately at the level of individual R&I projects. Value chain-level deliberation and coordination are required in delineating what norms such as "safety" constitute and require from new materials: what can be considered as safe, and how the safety risks and gains related to novel materials compare with those of currently available commercial materials. Kallergi and Asveld (2021) stress that regulatory bodies, institutionalizing norms and having authority over entire chains of industrial manufacturing, are in a key position to maneuver the development of new production modes and value chains. That said, the

governance of emerging value chains also requires knowledge exchange between R&I practitioners and regulators, in terms of communicating emergent opportunities, risks and requirements (Kallergi & Asveld, 2021). Furthermore, a "Quadruple helix" interaction between industry, research, regulatory governance, and civil society (e.g. consumer representatives) has been advocated for ensuring that different knowledge and value bases become heard at the level of innovation as well as its governance (Carayannis & Campbell, 2009; Mehari, et al., 2022; Popa, et al., 2020). We suggest that the meta-responsibility map with its guiding questions (Fig. 3.5) could be used to facilitate these interactions; to draw attention to differing and sometimes conflicting responsibilities, priorities, and goals among the value chain actors, to ensure that different aspects of responsibility become considered, and to spark discussion on how these could be addressed in a balanced and unbiased manner.

The following subsections present the responsibility imbalances of Table 3.4 in a more detail, together with their guiding questions.

3.4.3.1. Normative uncertainty

Various *norms* – such as standards, principles, values, or customs – prescribe criteria to decision making in R&I. In the BC and Bio2X cases, several norms can be identified which influenced the development of biomaterials, the most frequently mentioned being safety of use, resource efficiency, environmental sustainability (e.g., biodegradability), and cost competitiveness. Product quality features (e.g., durability, appearance) were also identifiable as norms.

We pose the guiding question 1 (*care – responsiveness*) of Fig. 3.5 to critically examine the normative basis guiding value chain formation, and to stimulate awareness that norms may have different interpretations. On a general level, many norms and values, such as safety or biodegradability, provide joint "normative anchor points" (von Schomberg, 2013) across an emerging value chain, influencing sentiments and decisions among its participants. For instance, both BC developers and consumer representatives brought up 'safety of use' as a key requirement for the proposed biocomposite. This indicates joint *care* for the impacts of novel materials – also amidst actors that are distant to each other in bio-based value chains such as material developers and consumers (Fig. 3.2). However, when put into practical contexts, the seemingly shared norms invoked different understandings and prioritizations among the actors. For instance, the consumers

in BC focus groups interpreted the safe usage of biocomposite in various ways, against a backdrop that biocomposite might undergo quality changes during long-term exposure to weather. While some consumers perceived safety as 'risk containment', preferring applications in which the biocomposite remained unexposed to weather, others regarded 'risk exposure' the safer choice, preferring outdoor applications where quality changes could be observed and monitored upfront (de Winter, 2021). To make implicit normative differences visible, a *responsive* mindset is required that involves questioning and mutual learning about the goals of innovation (Sonck, et al., 2020). Their early recognition, for instance among industrial R&I consortia or consumer focus groups, could reduce the risk for blind spots and misunderstandings forming at later stages.

On other occasions, acting according to a certain norm was limited because of competing obligations, such as occupational duties and economical boundary conditions. Guiding question 2 (*care* – *accountability*) in Fig. 3.5 highlights to what extent normative reasoning advocated by value chain participants (e.g., assuming *care* for societal impacts) eventually is reflected in their decisions and actions (i.e., their *accountability* for impacts). In line with Blok et al. (2017), ethical decision making not only involves recognition of a moral issue (what one deems right), but also leaves an impact footprint consistent with the identified values and norms (what one really does).

Blok et al. (2017) further exemplify that such ethical dilemma can arise between economic obligations and societal interests in innovation. In the BC case, many consumer representatives, whilst heralding environmental friendliness as a foreseeable benefit of the biocomposite, also indicated that for a positive purchase decision the biocomposite needs to be cheaper than the current alternatives on the market (de Winter, 2021). Among Bio2X developers, there was frequent deliberation regarding how economic requirements and societal motivations ought to be combined. On one hand, many respondents emphasized that the core accountability of corporate R&I – and their occupational duty – is to secure the future economic viability of the company. On the same note, many emphasized that within this frame, their project was driven forward by seeking synergies between profit-related goals (accountability) and societal benefits (care) of biorefining. For instance, resource-efficient solutions were seen reasonable both economically and environmentally. A limited number of respondents also contemplated a more fundamental shift taking place in business: To them, the 'mission' (and to an extent the accountability) of companies reached beyond creating value for shareowners, into creating value for societal stakeholders as well. This echoes the approach of Social Innovation, familiar in a business

context as innovation that explicitly aims at the creation of social value and thus positive social change (Lubberink, et al., 2017).

3.4.3.2. Regulatory uncertainty

Norms are often instigated and monitored by regulatory bodies. By setting requirements and standards for issues such as environmental and health impacts, regulatory frameworks formalize, prioritize, and institutionalize norms into *liabilities* obligating material manufacturers throughout the value chain. Possessing this capacity, regulatory institutions have a pivotal role as *authorities* directing the formation of new value chains.

It is known that existing normative guidelines and requirements can fall short of capturing opportunities and societal concerns related to novel technologies and products (Sonck, et al., 2017; Swierstra & Rip, 2007). BC developers also perceived environmental and safety regulations as incomplete, inconvenient, inappropriate, or outdated in the face of their R&I outputs, which brought about uncertainty regarding timelines and the overall success of their project (Kallergi & Asveld, 2021). With Fig. 3.5, we explicate identified mismatches between regulations and innovation as tensions between different aspects of responsibility. It should be noted that our findings are from a single R&I project and the viewpoints of policymakers and regulatory officials were not included in the scope of this study. Nevertheless, the findings illustrate that product safety and sustainability are not matters that individual R&I projects can resolve separately but need to be addressed at the system level and through policymaker incentives. Our findings also speak to the importance of dialogue between regulators and material developers, and for some questions, also with representatives of civil society, such as consumers. Guiding questions 3 – 6 of Fig. 3.5 are formulated to facilitate and to provide a responsibility frame for these interactions.

Guiding question 3 *(care – liability)* in Fig. 3.5 gauges the interface between regulations and societal norms, by asking if legislative and regulatory liabilities are in line with the value basis of society. It refers to situations where normative uncertainty (in guiding question 1) emerges at the level of legislation and regulations. This theme may have relevance in future studies on interactions involving policymakers and civil society representatives.

Guiding question 4 (*liability – accountability)* draws attention to the relevance and coverage of current regulations in light of opportunities and risks introduced by innovation. The BC developers felt that existing regulatory frameworks did not sufficiently grasp all foreseeable features and impacts of circular biocomposites. For instance, no standards were reportedly available for some emergent contaminants in wastewater, such as microplastics. Further, today's chemical registering requirements, based on conventional petrochemical polymers, were seen to make "chemically little sense" in the context of biopolymers. Also, no explicit end-of-waste criteria was available for wastewater feedstock (i.e., when waste stops being waste). Such mismatches are not only troublesome to R&I, but also mean failure in capturing what is relevant for novel materials and technologies in terms of safety (Kallergi & Asveld, 2021). Through the terminology of responsibility, this deficiency becomes explicated as discordance between *liability* (as 'what we have to prove'; legislation defining what impacts to follow and report) and *accountability* ('what we need to understand'; the intent to acknowledge and answer for the impacts of one's activities). R&I, by providing a knowledge of the properties of novel feedstocks, technologies and materials, could support legislators in capturing relevant risks and requirements for regulatory updates.

Guiding question 5 (*responsiveness – liability*) serves to spark discussion about creating a 'level playing field' between emerging and established industries. Some BC developers expressed concern that the present regulatory frameworks on safety may unintentionally slow down the market entry of novel bio-based and circular materials. It was remarked that safety requirements may be used as an argument, leading to a situation that favours established value chains. Today's risk culture was seen as less tolerant to newly introduced risks: one developer remarked that some currently available commercial goods would hardly be accepted if they were being developed today. There is a risk, according to many BC developers, that safety could be used as an argument to keep innovative materials off the market (Kallergi & Asveld, 2021). In terms of responsibility, the interviewees experienced an imbalance between the *liabilities* of complying with present legislation – which in this case were alleged to fortify the status-quo of established business – and *responsiveness* to emerging opportunities, which in this case would accelerate broader industrial renewal.

Guiding question 6 (*responsiveness – accountability*) hopes to trigger thinking about the right balance between risk taking and risk avoidance. It examines how regulation should respond to residual risks of novel materials which cannot be fully excluded through

technical measures within a moderate timeframe. The BC, while responding to an urgent need to improve resource efficiency for material manufacturing, produced a novel material without any track record regarding its long-term impacts and life expectancy. The developers noted that gaining compliance for safety standards, which are formulated and based on conventional materials, imply an unmanageable time lag between R&I and market launch. More generally, BC developers noted that even when the best measures available were taken to eliminate risks associated with novel materials, human activity involves risks and too much risk aversion will thwart innovation, new business, as well as attempts to respond to escalating environmental crises. In line with Sonck et al. (2020), tension appeared between the "innovation principle" promoting *responsiveness* (improving the current state of affairs and accepting a degree of residual risk), and the "precaution principle" emphasizing *accountability* (favouring the elimination of risks before acting). Balancing between the promises and risks of novel materials requires dialogue between innovators, policymakers, and civil society; in terms of which risks can be afforded to take and when precaution is non-negotiable (Kallergi & Asveld, 2021).

The sixth guiding question hopes also to inspire discussion about strategies on coping with residual uncertainties, which in the case of novel material innovations can never be fully foreseen nor eliminated. For instance, a stepwise, iterative development of biomaterials has been suggested to reduce time-to-market of new bio-circular materials, especially in terms of gathering long-term knowledge about material behaviors during the usage stage and through user experience (Asveld & Stemerding, 2017). At BC, developers as well as consumer representatives suggested the option of monitoring long-term impacts during usage, in response to uncertainty regarding the quality decline of biocomposites over time. When fed back upstream in the value chain, this knowledge could be applied by material developers in further adjusting material properties (Kallergi & Asveld, 2021). In R&I schemes, various approaches exist which support mutual learning between innovators and end users, such as focus groups, prototyping, and different methods of open innovation (e.g. Long and Blok, (2018); Sonck et al. (2020). At the value chain level, however, Kallergi and Asveld (2021) point out that current regulations are highly cautious towards leaving questions open when it comes to risks during usage. Also, whether biocomposite design is flexible enough to allow post-launch modifications based on the feedback remains somewhat questionable (Kallergi & Asveld, 2021). This echoes the famous Collingridge (1980) dilemma: While market launch will bring new knowledge about

the performance of the product in society, that product's properties are already locked-in by then, so that it has become too late to make changes at any bearable cost.

3.5. Conclusions and limitations

In this study, we examined responsibility networks in bio-based value chains against a backdrop that in today's industrial activity, responsibility for adverse societal impacts remains largely an unaddressed 'problem of many hands'. Our aim was to identify barriers and enablers of efficient and just responsibility allocation. This was accomplished by case studying value chains currently under formation, specifically during the R&I stage.

As a result, we first observed a tendency among R&I collaborators to define *accountabilities* as clearly as possible, which can be seen as a strategy against the diffusion of responsibilities or the 'problem of many hands'. Second, by looking into the actual *capacity* (response-ability) of the value chain actors to undertake accountability in different situations, we identified four critical reasons which severely limit the allocation of responsibility in bio-based value chains. First, accountability is diluted between value chain actors as materials from different origins are blended in multi-stage product manufacturing. Second, there appears to be no explicit authority demanding accountability for wider societal impacts. Moreover, normative goals (third) and regulations (fourth) fall short of providing clear directives to manufacturers in situations where emerging materials and production modes would bring about considerable changes to existing value chain structures, roles and conventions.

Following a meta-responsibility approach, we identified several R&I level enablers to address these limitations, operationalizing varying aspects of responsibility (Table 3.2 and Table 3.3). In conclusion, a few overarching themes should be spotlighted. First: In the toolbox of industry, there are well-established contractual and legal methods to specify, allocate, and transfer responsibilities when materials are handed over downstream in the value chain. Belonging to the domain of backward-looking responsibility, these practices (e.g., auditing, material safety documents) have received limited attention in earlier RRI literature and should be considered as pivotal elements of responsible innovation. Second: R&I, as a developer of future solutions, is required to anticipate changes in regulations (e.g., emerging environmental liabilities) and normative guidelines (e.g., consumer preferences) and respond to those 'in advance' through product and process development choices. In this role, R&I enacts as a *responsive* entity in the company. Third, *care* for contributing to

societal challenges influences decision making in R&I, incentivized by personal values (employee motivations) or joint normative anchor points (corporate strategic guidelines). Care and responsiveness, being forward-looking elements of 'collective stewardship', also become manifest in joint goal setting and problem defining by future value chain members in R&I consortia. This exemplifies a form of co-responsibility existing in the private sector context. When developed into a meta-responsibility approach, RRI becomes more equipped to support social responsibility without obscuring accountabilities between value chain actors.

However, these identified R&I-level practices are as such insufficient and give no reason to downplay the need for a systemic change towards a more comprehensive allocation of accountabilities in future value chains. On the contrary, our findings illustrate that societal requisites, such as safety or sustainability, are not matters that individual R&I projects can resolve separately but need to be addressed at the value chain level. Owing to their capacity to impose requirements over entire value chains, regulators and policymakers are in a strong position to do this. In this study, we explicated tensions and imbalances between regulation and biomaterial innovation by employing the terminology of responsibility. In response, a meta-responsibility map (Fig. 3.5) is proposed as a tool to support identifying different aspects of responsibility to ease interactions across emerging value chains. Along with innovators and regulators, meta-responsibility can be used to facilitate exchanges between other stakeholders as well, in line with the Quadruple helix model. Under a systematic approach to responsibility and its aspects, the academic community of RRI could have a facilitator role in quadruple partnerships.

Finally, we encourage further case studies to apply and further modify meta-responsibility mapping, within and outside the bio-based sector. There are, however, some limitations regarding the generalizability of the results of this study. Our findings were formulated based on a limited number of case studies. Further, owing to their research scope, these case studies paid less attention to certain crucial steps in bio-based value chains, such as the primary production of bio-based feedstock. Additionally, material and technology developers are over-represented in our data, leaving some important stakeholder groups without their own voice, i.e., policymakers and non-governmental organizations. Further case-studying which covers various project types and modes of collaboration, stakeholders, R&I maturity stages, and industrial sectors is required.

References

Alexander, R. (2020). Emerging roles of lead buyer governance for sustainability across global production networks. *Journal of Business Ethics* 162(2), 269-290.

Asveld, L. & Stemerding, D. (2017). Social learning in the bioeconomy: The Ecover case. In I. van de Poel, L. Asveld & D.C Mehos (eds.) *Experimentation beyond the laboratory. New perspectives on technology in society*, (pp. 103-124). Routledge, London, UK.

Blok, V., Hoffmans, L. & Wubben, E. F. (2015). Stakeholder engagement for responsible innovation. *Journal on Chain and Network Science* 15(2), 147-164.

Blok, V. & Lemmens, P. (2015). The emerging concept of responsible innovation. Three reasons why it is questionable and calls for a radical transformation of the concept of innovation. In B.J. Koops, I. Osterlaken, H. Romijn, T. Swierstra & J. van den Hoven (eds.), *Responsible Innovation 2: Concepts, Approaches, and Applications*, (pp. 19-35). Springer, Cham, Switzerland.

Blok, V., Tempels, T., Pietersma, E. & Jansen, L. (2017). Exploring Ethical Decision Making in Responsible Innovation: the case of innovations for healthy food. In L. Asveld, R. van Dam-Mieras, T. Swierstra, S. Lavrijssen, K. Linse & J. van den Hoven (eds.), *Responsible Innovation 3: A European Agenda?*, (pp. 231-249). Springer, Dordrecht, The Netherlands.

Carayannis, E. G. & Campbell, D. F. J. (2009). 'Mode 3' and 'Quadruple Helix': toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management* 46(3-4), 201-234.

Ceicyte, J. & Petraite, M. (2018). Networked responsibility approach for responsible innovation: Perspective of the firm. *Sustainability* 10(6), 1720.

Ceicyte, J., Petraite, M., Blok, V. & Yaghmaei, E. (2021). Responsible innovation in industry: The role of firm's multi-stakeholder network. In E. Koukios & A. Sacio-Szymanska (eds.), *Bio# Futures*, (pp. 581-603). Springer, Cham, Switzerland.

Chatfield, K., Iatridis, K., Stahl, B. & Paspallis, N. (2017). Innovating responsibly in ICT for ageing: Drivers, obstacles and implementation. *Sustainability*, 9(6), 971.

Collingridge, D. (1980). The Social Control of Technology. Frances Pinter, London, UK.

De Winter, M. (2021). *Public perceptions on three different applications of bio-composites made from recovered resources.* TUDelft, Delft, the Netherlands. Available by request from the lead author.

Dreyer, M., Chefneux, L., Goldberg, A., von Heimburg, J., Patrignani, N., Schofield, M. & Shilling, C. (2017). Responsible innovation: A complementary view from industry with proposals for bridging different perspectives. *Sustainability* 9(10), 1719.

Felt, U. (2017). "Response-able practices" or "new bureaucracies of virtue": the challenges of making RRI work in academic environments. In L. Asveld, R. van Dam-Mieras, T. Swierstra, S. Lavrijssen, K. Linse & J. van den Hoven (eds.), *Responsible Innovation 3: A European Agenda?,* (pp. 49-68). Springer, Dordrecht, The Netherlands.

Ghisellini, P., Cialani, C. & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production* 114, 11-32.

Ha-Brookshire, J. (2017). Toward moral responsibility theories of corporate sustainability and sustainable supply chain. Journal of Business Ethics 145(2), 227-237.

Kallergi, A. & Asveld, L., 2021. *Biocomposite: Safe-by-design for the circular econonomy*. Available at: https://www.researchgate.net/publication/356917394_Biocomposite_Safe-by-Design_for_the_circular_economy [Accessed on 22 March 2022].

Long, T. B. & Blok, V. (2018). Integrating the management of socio-ethical factors into industry innovation: towards a concept of Open Innovation 2.0. International Food and Agribusiness Management Review 21(4), 463-486.

Lubberink, R., Blok , V., van Ophem, J. & Omta, O. (2017). Lessons for Responsible Innovations in the Business Context: A Systematic Literature Review of Responsible, Social and Sustainable Innovation practices. *Sustainability* 9(5), 721.

Mehari, J., Pekkola, E., Hjelt, J., Yuzhuo, C., Stenvall, J. & Ortega-Colomer, F.J. (2022). Defining 'Responsible' in Responsible Research and Innovation: The Case of Quadruple Helix Innovation in the Energy Sector in the Tampere Region. In C. Paunescu, K. Lepik & N. Spencer (eds.), *Social Innovation in Higher Education*, (pp. 199-225). Springer, Cham, Switzerland.

Murray, A., Skene, K. & Haynes, K. (2017). The circular economy: an interdisciplinary exploration of the concept and application in a global context. *Journal of Business Ethics* 140(3), 369-380.

Nielsen, M. V. (2016). The concept of responsiveness in the governance of research and innovation. *Science and Public Policy* 43(6), 831-839.

Noorman, M., Swierstra, T. & Zandbergen, D. (2017). Questioning the normative core of RI: the challenges posed to stakeholder engagement in a corporate setting. In L. Asveld, R. van Dam-Mieras, T. Swierstra, S. Lavrijssen, K. Linse & J. van den Hoven (eds.), *Responsible Innovation 3: A European Agenda?,* (pp. 231-249). Springer, Dordrecht, The Netherlands.

Owen, R. et al. (2013). A framework for responsible innovation. In R. Owen, J. Bessant & M. Heintz (eds.), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*, (pp. 27-50). John Wiley and Sons, Chichester, UK.

Palmeros Parada, M., Asveld, L., Osseweijer, P. & Posada, J.A. (2018). Setting the design space of biorefineries through sustainability values, a practical approach. *Biofuels, Bioproducts and Biorefining* 12(1) (29-44).

Pellé, S. & Reber, B. (2015). Responsible innovation in the light of moral responsibility. *Journal on Chain and Network* Science 15(2) (107-117).

Pellizzoni, L. (2004). Responsibility and environmental governance. Environmental Politics 13(3) (541-565).

Popa, E.O., Blok, V. & Wesselink, R. (2020). A processual approach to friction in quadruple helix. *Science and Public Policy* 47(6) (876-889).

Rome Declaration on Responsible Research and Innovation in Europe (2014). Available at: https://digital-strategy.ec.europa.eu/en/library [Accessed on 22 March 2022].

Sonck, M., Asveld, L., Landeweerd, L. & Osseweijer, P. (2017). Creative tensions: mutual responsiveness adapted to private sector research and development. *Life Sciences, Society and Policy* 13(1) (1-24).

Sonck, M., Asveld, L. & Osseweijer, P. (2020). Meta-responsibility in corporate research and innovation: A bioeconomic case study. *Sustainability* 12(1) (38).

Stahl, B.C. (2013). Responsible research and innovation: The role of privacy in an emerging framework. *Science and Public Policy* 40(6) (708-716).

Stilgoe, J., Owen, R. & MacNaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy* 42(9) (1568-1580).

Swierstra, T. & Rip, A. (2007). Nano-ethics as NEST-ethics: patterns of moral argumentation about new and emerging science and technology. *Nanoethics* 1(1) (3-20).

Thompson, D. F. (1980). Moral responsibility and public officials: The problem of many hands. *American Political Science Review* 74(4) (905-916).

Timmermans, J., Yaghmaei, E., Stahl, B. C. & Brem, A. (2017). Research and innovation processes revisited: networked responsibility in industry. *Sustainability Accounting, Management and Policy Journal* 8(3) (307-334).

van de Poel, I., Asveld, L., Flipse, S., Klaassen, P., Scholten, V. & Yaghmaei, E. (2017). Company strategies for responsible research and innovation (RRI): A conceptual model. *Sustainability* 9(11), (2045).

van de Poel, I., Nihlén Fahlquist, J., Doorn, N., Zwart, S. & Royakkers, L. (2012). The Problem of Many Hands: Climate Change as an Example. *Science and Engineering Ethics* 18(1) (49-67).

van de Poel, I. & Sand, M. (2018). Varieties of responsibility: two problems of responsible innovation. *Synthese* 198(19) (4769-4787).

Von Schomberg, R. (2013). A vision of responsible research and innovation. In R. Owen, J. Bessant, M. Heintz. (eds.), *Responsible Innovation: Managing the responsible emergence of science and innovation and society*, (pp. 51-74). John Wiley and Sons, London, UK.

Zwart, H., Landeweerd, L. & van Rooij, A. (2014). Adapt or perish? Assessing the recent shift in the European research funding arena from 'ELSA' to 'RRI'. *Life Sciences, Society and Policy* 10(1) (11).

Chapter 4

Creative tensions: Mutual responsiveness adapted to private sector research and development

This chapter has been published as:

Sonck, M., Asveld, L., Landeweerd, L., Osseweijer, P. Creative tensions: mutual responsiveness adapted to private sector research and development. *Life Science, Society and Policy* 13(1), 1–24.

4.1. Introduction

There are calls on companies to respond to the needs of societies within which they operate, beyond securing short-term profitability and complying with regulations. In Europe, this call has recently been voiced in the field of *Responsible Research and Innovation* (RRI), a research policy approach that has been coined in the European Commission's policy context as the most recent framework to address societal dimensions of science and technology. RRI builds on the one hand on its earlier research policy counterparts, such as ELSA (ethical, legal and social aspects). On the other hand, RRI is developed further through several emerging research approaches that can be captured under the heading of 'responsible innovation'. From these premises, RRI posits that Research and Development (R&D) processes should anticipate and reflect societal aspects of the innovation, but also that innovators are expected to be *responsive* to these considerations by adjusting the shape (e.g. design) and direction of the innovation (Owen et al., 2013; Stilgoe, Owen, & Macnaghten, 2013). Furthermore, stakeholder involvement is a substantial element in all RRI approaches (Koops, 2015). It is emphasised that R&D should be an inclusive process, involving interaction between innovators and societal stakeholders, who become *mutually responsive* 'to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products' (von Schomberg, 2013).

Increasing attention within the RRI community is now turning towards private sector R&D. Given that RRI challenges both innovators and stakeholders to be active contributors to the responsibility of innovation processes and its outcomes, the question arises, how their interaction can best be organised to enable *mutual responsiveness*. As Stirling already claimed in 2008, stakeholder involvement is about *opening-up* the innovation to 'participatory deliberation' about its goals and purposes in society. RRI posits that in the course of this process, the innovators and stakeholders would become mutually responsive, implying that they reach some form of a joint understanding about how the innovation is shaped, and eventually applied. Deliberation can then be *closed-down* and decisions made in order to move on with the innovation (Stirling, 2008).

So far, the understanding of mutual responsiveness in RRI has been criticised for being highly naive: as unconcerned about private sector characteristics. In particular, it is assumed that innovators and stakeholders engage continuously in a transparent process,

and also end up sharing responsibility. In reality, corporate innovation is characterised by high investment and risk imbalances, as well as power and information asymmetries. (Blok & Lemmens, 2015) What are the chances of *opening-up* the innovation to participatory deliberation in face of such asymmetries? Further, understanding of mutual responsiveness appears highly demanding in its optimism about resolving the discrepancies between stakeholder needs and perspectives. To become mutually responsive requires learning, interdependence, trust to take place among actors with very different needs and interests. (Nielsen, 2016) How can we *close-down* the deliberation in face of these differences? These shortcomings partly indicate that RRI's conceptualisation is still open-ended, with little detailed description of what mutual responsiveness could imply in practical innovation contexts (with exceptions like Blok (2014) and Haen et al. (2015)). Furthermore, RRI and its predecessors have been mainly developed in policy and academic contexts (Blok & Lemmens, 2015; Scholten & van der Duin, 2015), and the literature on stakeholder involvement largely centres around public policies and science governance (cf. Delgado, 2010; Ganzevles & van Est, 2012). These contexts may partly capture different problematics and opportunities than the company environment.

Recently, Blok et al. (2015), Noorman et al. (2017) and Blok et al. (2017) have each explored how private sector R&D complies with RRI's ideas. While these case studies conclude that the case companies fell short of the idea of mutual responsiveness via continuous multi-stakeholder collaboration, they also bring out 'reasonable reasons' for why such collaboration is not always possible – or desirable. What is more, the studies portray alternative management practices to interrogate stakeholders' perspectives, and respond to those in the course of R&D.

This paper draws inspiration from the discrepancies between RRI's idea of mutual responsiveness, and how stakeholders were actually involved in private sector R&D in these recent case studies. Our main question is: How could responsiveness be operationalized in R&D, given the limitations of mutual responsiveness identified in practical innovation environments? By paralleling RRI-related theory and practice, we will suggest three further elaborations for the concept of responsiveness as an answer to our question. **Process-responsiveness** is suggested for identifying situations, which particularly require opening-up of the innovation at R&D level. **Product-responsiveness** is suggested for mobilising the potential of R&D's products to be adaptable to diverse stakeholder needs. ***Pre*sponsiveness** is suggested as responsiveness towards stakeholders that are not (yet) reachable at the time of R&D. The aim in presenting these elaborations is to

contribute to a more tangible concept of responsiveness in RRI, while also suggesting directions for analysis in upcoming case studies.

The article will unfold as follows. Section 4.2 introduces theoretical background and the case studies. In section 4.3, we will discuss the tensions between theory and practice in a more detail, and as an outcome suggest the elaborations for the concept of responsiveness. In conclusions (Section 4.4), we briefly reflect on generalizability and limitations of the outcomes.

4.2. RRI and responsiveness

The term 'responsiveness' embodies many core elements of RRI's conception for responsible innovations. As the *action element* of RRI, responsiveness mobilises the societal input into explicit actions in innovations, so that the innovation becomes better aligned with societal needs (Flipse et al., 2015; Owen et al., 2013). Further, responsiveness as *forward-looking responsibility* signifies a 'receptive attitude' of reacting and responding to new knowledge as it emerges, while acknowledging the uncertainty and limited control that are inherent to innovations (Pellizzoni, 2004; Stilgoe et al., 2013). From this standpoint, societal challenges appear as positive triggers for socio-economic improvements, which according to RRI are attainable through innovations, provided that there are (continuous) efforts to discuss and define societal 'right impacts' and 'right processes' for their implementation (Zwart et al., 2014). Furthermore, to be responsive also embodies a *relationship* between innovators and societal stakeholders. *Mutual responsiveness* highlights reciprocity and proactivity in this relationship, in that the actors are expected to jointly shape and direct the innovation towards realising the 'right impacts'. This definition excludes, for instance, unidirectional 'pushing' of information to public about latest technical advances, or 'pulling out' valuable knowledge or confidence about acceptability from the public (Lee & Petts, 2013; Stirling, 2008).

To become mutually responsive, innovators and different stakeholders are first expected to recognise differing perspectives on the innovation, and then to become attentive to others' perspectives – and critical of their own. This would lead to a form of a joint understanding, such as consensus, agreement on courses of action (Asveld & Stemerding, 2017), alignment of expectations, acceptance of conflict (agreeing to disagree) (Blok et al., 2015), or re-constructing of the self (cf. Blok, 2014, for dialogical responsiveness). Hence, mutual responsiveness demands reflexivity and learning between

actors with different interests, trust and interdependence, as well as commitment to jointly find long-term solutions to societal challenges (Flipse et al., 2014; Nielsen, 2016). From innovators, mutual responsiveness asks readiness to provisionally acknowledge the legitimacy of raised concerns (Haen et al., 2015). From stakeholders, it requires a constructive input in terms of defining what is societally desirable (von Schomberg, 2013), and hence willingness to think and speak about concerns (Haen et al., 2015). Not the least demanding, mutual responsiveness is described as resulting from continuous and transparent exchange of information (e.g. via stakeholder dialogue), and is assumed to lead to sharing responsibility among the actors (von Schomberg 2013; Blok et al. 2015).

4.2.1. Mutual responsiveness: *why*, *how*, *with whom*

Several challenges regarding RRI's ideas of multi-stakeholder activities have been identified. With regard to backward-looking responsibilities (Pellizzoni, 2004), there are for instance concerns whether blurring of role differentiation would lead to unclear distribution of accountability (Landeweerd, 2017; Zwart et al., 2014). With our focus on responsiveness (i.e. forward-looking responsibility), we assume in this paper that accountability remains with the innovator. We also assume this, since companies (investing in new innovations) and their stakeholders seem to agree that the investor alone is responsible, when it comes to making investment decisions (Blok et al., 2015). Focusing on responsiveness, we will thus elaborate challenges faced by ideas of *mutually responsive* relations among innovators and stakeholders. To mobilise further theories for discussing the challenges identified in the case studies, we pose three guiding questions about mutual responsiveness.

Our first question is: *Why should the private sector R&D and stakeholders become mutually responsive?* In Section 4.3.1, we will reflect on RRI's idea of frequent stakeholder involvement against situations, where companies (allegedly) were already responsive to societal needs without a need for such involvement. These situations bring up two distinctive, but not mutually exclusive, approaches in RRI on how to operationalise responsiveness in innovations (Blok et al., 2017). In the more *normative approach*, innovation can be responsive by applying normative 'anchor points' (von Schomberg, 2013) as its goals, such as sustainability or public health. The normative approach builds on substantive rationale, in the sense that the reason for involving stakeholders is to obtain better results, such as improved public health (Delgado et al., 2011; Fiorino, 1989; Stirling, 2008). Correspondingly, the processes are less fixed and thus amenable to adjustments

according to their relevance for the outcome. On the other hand, *procedural approach* posits that responsible innovation *is* a deliberative and inclusive process (Blok et al., 2017). The rationale is in procedural norms: stakeholder involvement is 'the right thing to do' for the sake of the process (e.g. following an ideal of democracy) (Delgado et al., 2011; Fiorino, 1989; Stirling, 2008). Thus, outcomes are less fixed and more amenable to influence by the public demand (Blok et al. 2017). An application of procedural approach is also the framework by Owen et al. (2013) whereby responsible innovation is a process of inclusive anticipation and reflection, resulting in a response steering the innovation.

Second, if the innovation is to be opened-up: *How can the private sector R&D and stakeholders become mutually responsive?* Section 4.3.2 will bring up several limitations that stood out in the case companies' efforts for involving stakeholders during R&D. Further, case studies display an array of management practices for involving stakeholders – given these limitations. We highlight the need to consider these practices in the context of their purpose. For this, we evoke Stirling's (2008) distinction between *appraisal* (i.e. informing decision making) and *commitment* (forming tangible decisions on particular innovation trajectories). Appraisal and commitment can involve both *opening-up* as well as *closing-down* the innovation. *Opening-up appraisal* can provide 'plural advice' for innovators, as it welcomes diverging societal discourses and framings in the discussion, and weighs alternative courses of action. In contrast, *closing-down appraisal* is prone to support decision makers' 'incumbent interests' and instrumental behaviour: discussion already excludes alternative framings and courses of action in advance. In the time of commitment, some degree of closing down is necessary and desirable in order to move on, but Stirling also remarks that this *closing-down commitment* tends to be 'unduly privileged'. He suggests that consideration should also be given to *open-ended commitments*, as they leave space for diversity, and promote context sensitivity, avoidance of lock-ins, and social learning.

The third question is: *With whom should the private sector R&D become mutually responsive*? Section 4.3.3 will discuss situations, in which opening-up the innovation for stakeholder engagement was perceived as non-informative during early steps of R&D, indicating also uncertainty about who should count as a stakeholder. Here, we return to the definition of responsiveness as future-oriented responsibility, which obliges a 'receptive attitude towards needs and desires of others, before deciding what to do' (Pellizzoni, 2004). Yet, how can there be mutual responsiveness among the innovators and those actors, who are potentially affected by the innovation but are not available at the

context of R&D? We approach this question in view of the Collingridge dilemma (Collingridge, 1980) that has been widely discussed in RRI-related literature (e.g. Blok & Lemmens, 2015; Flipse et al., 2013; Owen et al., 2012). That is: In its early steps an innovation would be better amenable for modifications based on stakeholder input, but there is not enough knowledge for grasping the impacts of the innovation on society. Conversely, by the time the concept is explicit enough to allow diverse societal reflections, it is already locked-in to certain trajectories so that steering the innovation is difficult, costly and time consuming.

4.3. Case studies

We will discuss these guiding questions principally based on three case studies from RRI literature: one from the ICT sector (Noorman et al., 2017) and two from the food sector (Blok et al., 2015; Blok et al., 2017). These studies were chosen as they are 'exploratory': They examine decision-making in private sector R&D from RRI perspectives, based on actual data from the companies (interviews, surveys, observation). Furthermore, the studied companies are aiming to address societal challenges with their innovations, thus having 'societal aspirations' (Noorman et al., 2017) and 'disposition to innovate more responsibly' (Blok et al., 2015). Furthermore, their stakeholders include non-commercial actors, in addition to commercial partners.

Noorman et al. (2017) introduce a start-up with a pseudonym **Datashare**, developing an online digital platform that would allow residents, government organisations, and service providers to exchange information about energy consumption. Datashare aims to develop the platform for 'privacy-friendly data sharing', enabling both the resident-users to control their own data, and the business partners to access the resident data. With this aim, Datashare needs to balance between conflicting interests and values (privacy and access) of their key stakeholders. To address this conflict, Noorman and colleagues proposed a stakeholder workshop, inviting residents, business partners, and privacy-oriented civil society organisations (CSOs), to jointly reflect upon implicit values, biases and interests regarding the platform. This proposal was dismissed by Datashare, which led the authors to explore 'reasonable reasons' restricting stakeholder involvement. Further, it led the authors to explore how Datashare attempted to be responsive to stakeholder needs and values within these restrictions, through 'tinkering and improvisation'.

Blok et al. (2015) studied several **Dutch food companies** and their non-commercial stakeholders, in order to find out to what extent companies with a disposition to innovate more responsibly are moving towards the idea of mutual responsiveness. For this, the authors examined to what extent companies engage stakeholders at different steps of the innovation process. They conclude, that the companies fall short of the ideal of mutual responsiveness as a transparent and interactive relation leading to sharing responsibility. Stakeholder engagement was not continuous, as it mostly took place at strategic level and early R&D phase (idea generation), and sometimes as an 'extra check' in the late (commercialisation) phase. In the middle (developmental) phase, stakeholders were rarely involved and only under strict intellectual property conditions. The authors then identified several critical issues restricting transparency, interaction, responsiveness and co-responsibility in private sector R&D settings. Moreover, several management practices to deal with these critical issues were identified.

Blok et al. (2017) studied food companies that participate in a front-of-package (**FoP**) logo for healthier food products. The authors explored, to what extent the companies contributing to global health challenges consider social-ethical factors in their R&D. By applying the stage-gate model (Cooper, 1990), and Jones's (1991) theory of ethical decision making, the authors conclude that ethical decision making did not occur at any step of the R&D process. Further, stakeholders were not involved in the decision making process during R&D. However, the authors suggest that ethical decisions, such as trade-offs between health benefits and techno-economic factors, had possibly been made at a higher strategic level, where stakeholders like health organisations could also have been involved. These strategy-level decisions then set boundary conditions for R&D, within which R&D then focuses on techno-economic factors (e.g. quality, costs).

From here on, these cases will be referred to as **Datashare case**, **Dutch food case**, and **FoP** case, respectively. Due to the small number of cases, we also refer to a number of *background case studies* in the RRI literature, which are not 'exploratory' in every aspect of our definition, but can further elucidate the findings. Asveld & Stemerding (2017) describe a case in which companies developing a bio-based cleaning product were targeted by a critical campaign by environmental CSOs. The authors illustrate how mutual learning among stakeholders could have been organised during the R&D process, in order to unveil differing notions on what is 'sustainable'. Balkema & Pols (2015) investigate negative socio-economic and environmental impacts of biofuel crop cultivation in Tanzania, affecting the hardest the most vulnerable stakeholders, the small farmers. By means of an ethical

framework the authors identify responsibilities of each stakeholder, concluding that such identification during stakeholder engagement would have been precondition for a sustainable biofuel innovation. Dignum et al. 2016) studied stakeholder argumentation for and against shale gas exploitation in the Netherlands, based on which they examine applicability of Value-Sensitive Design (VSD) in the design of stakeholder participation processes. Haen et al. (2015) organised public engagement exercises around novel food products, while developing a tool to unveil and address ethical, cultural and political concerns that often appear to be overlooked in food innovations. Scholten and van der Duin (2015) studied the extent to which spin-off companies from academia are applying elements of responsible innovation. In a survey of a sample of start-ups in the Netherlands, the authors' findings included that 'social responsiveness' (inclusion of the social aspects of what the firm produces and develops in the innovation) increases the companies' capacity to absorb external knowledge, and to apply that knowledge in their innovations. Finally, van den Hoven (2013) discusses public debates around smart electricity meters and electronic healthcare records, and reflects on the potential of VSD to make conflicting values (e.g. privacy, resource efficiency, access) explicit and accommodated in the product design.

4.4. Implementing mutual responsiveness in the private sector

This section suggests process-responsiveness, product-responsiveness, and *pre*sponsiveness as further elaborations for the concept of responsiveness (See Fig. 4.1). Before each elaboration, we first describe limitations that stood out in case studies as challenging RRI's idea of mutual responsiveness. Namely, the studied companies perceived several 'critical issues' (Blok et al., 2015) and 'reasonable reasons' (Noorman et al., 2017) limiting stakeholder collaboration. After each elaboration, we present discussion that led to our suggestions. The discussion reflects RRI theories with 'management practices' (Blok et al., 2015) that the companies applied for dealing with the challenges in their stakeholder collaboration.

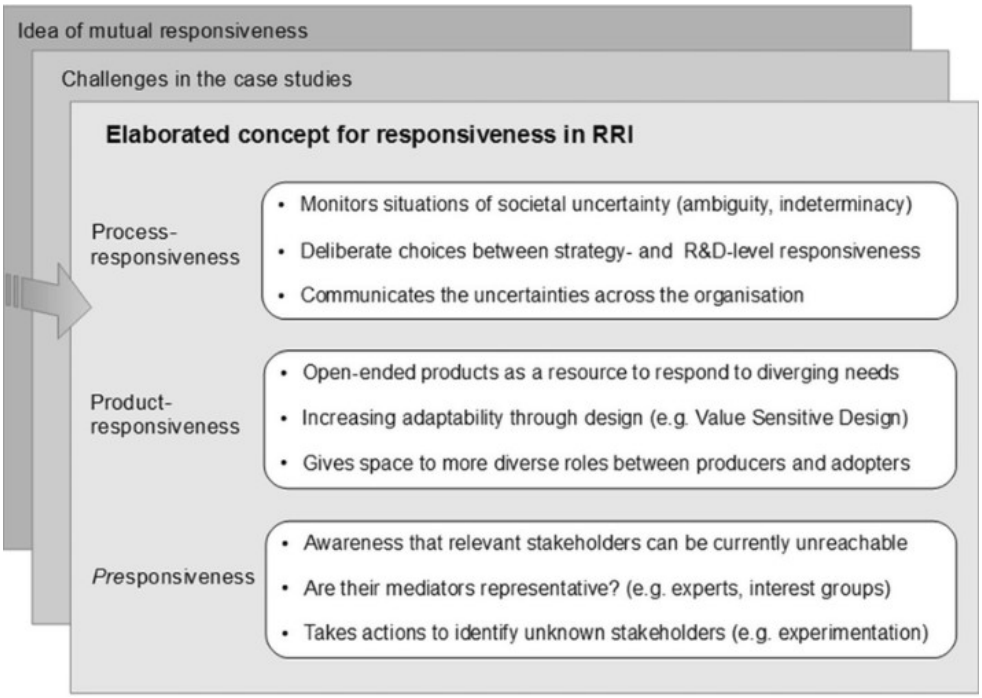

Figure 4.1. Three elaborations for the concept of responsiveness in RRI.

4.4.1 Why become mutually responsive: Process-responsiveness

Limitation: No perceived need for mutually responsive R&D. The case companies did not always perceive a need to consider societal aspects of their innovation at R&D level, nor involve stakeholders for this. Instead, they pursued their societal aspirations by other means. Both the FoP companies (Blok et al., 2017) and Dutch food companies (Blok et al., 2015) applied healthy food criteria agreed upon by their stakeholders, as mandatory boundary conditions for the operational R&D. Within these boundaries, the R&D then focused merely on techno-economic issues. The decision to adopt these criteria had been made at the corporate strategy level – possibly involving also stakeholders like health organisations. In addition, Dutch food companies organised stakeholder rounds during early R&D, but expressed that frequent stakeholder involvement was often not necessary

after the early steps, as 'science does not change every week' and stakeholder opinions hardly change that suddenly (Blok et al., 2015).

4.4.1.1. Suggestion: Process-responsiveness

These findings are in line with recent conclusions that Corporate Responsibility approaches often receive little consideration at the R&D level. While companies have adopted strategies to address societal and environmental impacts of their operations, such as Corporate Social Responsibility (CSR) (cf. Iatridis & Schroeder, 2016; Pellé & Reber, 2015), social and ethical aspects are still not usually included in the 'throughput' (Blok & Lemmens, 2015), or 'midstream' (Flipse 2012), of innovation processes. This bears a risk of discrepancies forming between strategic and operational levels (Blok et al., 2017). Furthermore, there are retrospective studies on unsuccessful projects suggesting that *opening-up* the innovation to stakeholder perspectives during the R&D process could have enhanced both the acceptability and commercial success of the project (e.g. Asveld & Stemerding, 2017.; Dignum et al., 2016).

Against this background, we suggest the **process-responsive** approach as a step to further operationalise responsiveness in innovations. Process-responsive innovation:

- Makes deliberate choices between adopting a more normative (strategy-level) or a more procedural (R&D-level) approach to responsible innovation.
- Considers the extent of uncertainty in making these choices. When the normative approach is followed, remains alert to uncertainties that call for opening-up the innovation at the R&D level to wider reflections on its goals and purposes. Such situations include, among others, application of emerging technologies (high ambiguity) and radical innovations (indeterminate uncertainty).
- Encourages communication between R&D and the strategy level about the uncertainties, for example via organisational culture and structures that support such interaction.

Process-responsiveness also makes RRI more explicit about what is expected of company innovators, if they are to become mutually responsive with societal actors with a view to the societal aspects of the innovation (von Schomberg, 2013). Simultaneously, it

further elaborates responsiveness as the *action element* of RRI, by suggesting the deliberate choice between normative and procedural approach as one form of such action.

4.4.1.2. Reflecting R&D and practice

As Blok et al. (2017) note, FoP companies' practices run contrary to some of RRI theory expectations. One the one hand the companies were responsive to the societal need for healthier food, by following criteria (e.g. salt and calorie levels) that are in line with normative societal goals (public health). In this normative sense, they were attentive to the 'right impacts' of the innovation regarding the impact of their products (Blok et al., 2017; Owen et al., 2012; von Schomberg, 2013). Yet, their approach was inconsistent with the procedural approach: R&D did not anticipate societal impacts or reflect purposes of the innovation, to any extent identifiable in their decision making (Blok et al., 2017). Just as little was there any inclusive opening-up of the innovation during R&D to the perspectives of societal actors (Owen et al., 2012; Stirling, 2008), and hence no mutual responsiveness at the R&D level.

However, Blok et al. (2017) suggest that companies had weighed trade-offs between ethical and techno-economic aspects, such as between salt level and shelf-life, at the corporate strategy level. Furthermore, stakeholders like health organisations may have had an influence on the companies' innovation agendas via strategy-level dialogue, although this was out of the scope of the FoP study. Thus, there appears a more normative alternative of operationalising responsiveness at the strategy-level, compared with a more procedural approach focusing on the R&D level. The healthy food criteria functioned as 'downstream carriers' of the normative goals to R&D operations. Like in Dutch food companies (Blok et al., 2015), the normative approach can be supported with some stakeholder engagement during early-phase R&D, and during later R&D phases with supervision by higher management that the stakeholder demands are taken into account.

With support of RRI literature, we can tentatively delineate benefits and risks of the more normative, strategy-level responsiveness. Regarding the benefits: clear strategic guidelines could help to sustain ethical aims, as the ethicality of the innovation lies less on the shoulders of individual teams and team members. Strategic guidelines can bring continuity, for example when an R&D project proliferates into several parallel trajectories (e.g. Datashare case: Noorman et al., 2017), or when the R&D team changes. Furthermore, a clear division of labour safeguards scarce resources: When societal goals are managed at

the strategy level, R&D's resources can be focused on techno-economic development. This may be particularly vital, when strict health criteria pose additional challenges for developing a techno-economically viable product (Blok et al., 2015). Furthermore, the public roles of higher managers can be more supportive to societal reflection. For example, CEO's are expected to take public stands on wider issues regarding the companies' activities (Asveld & Stemerding, 2017).

On the other hand, it is questionable to what extent the strategy-level alone can grasp societal impacts of innovations as future-oriented activity bound with uncertainties. In line with van de Poel (2017) and Asveld & Stemerding (2017): innovations uphold three types of uncertainties. Epistemological uncertainty arises from lack of knowledge, and can usually be reduced by further research at any phase. Indeterminate uncertainty is experienced when several options for the course of the innovation are still open, and can be resolved only as the innovation becomes 'done' and introduced in society. Ambiguous uncertainty arises from diverging viewpoints of societal actors on a specific topic, which are often of moral nature and thus hard to falsify or prioritise. In the FoP and Dutch food cases, the healthy food criteria appear to enjoy a broad societal consensus, making them societally representative guidelines. That is: the criteria appear objective (low epistemological uncertainty), applicable incrementally (low indeterminate uncertainty), and undisputed (low ambiguous uncertainty). From this viewpoint, there appears little uncertainty or 'moral intensity' (Blok et al., 2017; Jones, 1991) to incentivise companies to ethical reflections and stakeholder involvement during the R&D process.

Ambiguous uncertainty. However, in situations of high ambiguous uncertainty, a broader and more inclusive reflection on the guiding norms may become vital for the acceptability and overall success of the innovation. Disagreement about 'right impacts' of the innovation implies that existing normative guidelines may fall short of representing stakeholder perspectives and capturing societal concerns. This is a known risk when new and emerging technologies are applied in innovation (Owen et al., 2013; Swierstra & Rip, 2007). Novelties such as synthetic biology or nanotechnology can 'rob moral routines' and turn them into topics of deliberation and reconsideration (Swierstra & Rip, 2007). This was noted also by one of the Dutch food companies: when any emerging issue is involved that society is not widely familiar with (e.g. use of fish oil in foods), much more discussion is needed to develop health criteria that both companies and stakeholders can agree upon. In such cases, some companies also asked stakeholder opinions in the late

(commercialisation) phase, as an 'extra check' that can have an impact on the market launch. (Blok et al., 2015)

Ambiguous uncertainty can also appear when innovations incorporate values that are prone to conflict, such as privacy and access (Noorman et al., 2017.; van den Hoven, 2013) or environmental qualities and economic competitiveness (Owen et al., 2012). Further, seemingly undisputed values may turn out to be ambiguous, such as 'environmental friendliness' in debates concerning shale gas exploitation (Dignum et al., 2016), or 'sustainability' in the Ecover case (Asveld & Stemerding, 2017). The latter describes two companies developing a bio-based detergent, which faced unexpected critique from a CSO, leading to the dismissal of the project near the product launch. While the companies assessed sustainability in terms of climate change mitigation, the CSO stressed impacts on biosafety (novel biotechnologies were involved), and socio-economic aspects of sustainability (negative impacts on third world farmers). The authors argue that stakeholder involvement would have revealed the differing understandings and value frames behind the seemingly uniform goal of sustainability, possibly saving the project. (Asveld & Stemerding, 2017)

Indeterminate uncertainty. Even when strategy-level decisions are furthered with stakeholder involvement in the early R&D phase, it may not suffice for addressing ambiguities. Indeterminate uncertainty implies that some ambiguities appear and become tangible only as the innovation proceeds (van de Poel, 2017). These 'unknown unknowns' are intrinsic to innovations (e.g. Pellizzoni, 2004), implying that we cannot fully know beforehand the extent of the unknown (Swierstra & Rip, 2007), and what all can go wrong (van de Poel, 2011). This indeterminacy appears the more pertinent, the more radical the innovation is: when the outcomes are not applicable with incremental changes to existing structures, practices and systems (Swierstra & Rip, 2007). Thus, whereas high ambiguity calls for societal deliberation on the 'right impacts' of an innovation, high indeterminacy suggests that such ambiguities may be best explored throughout the development process, as part of the hands-on R&D work.

Communicating uncertainties. Given that Corporate Social Responsibility (CSR) strategies often remain distant from R&D, further attention may be required to secure enough exchange of information between R&D and strategy management about ambiguous and indeterminate uncertainties. For example: do 'organisational factors' such as corporate structures and culture (Blok et al., 2017; Jones, 1991) also encourage

communication 'upstream' – from R&D to strategy management? Active communication about successes and failures regarding normative guidelines along the R&D process could reduce the risk of the escalation of discrepancies between strategy and practice: for instance by exposing needs to readjust 'downstream' carriers like health criteria, or needs to reconsider the strategy.

In summary: With process-responsiveness, we suggest to consider the extent of uncertainty in weighing whether to open-up the innovation at (procedural) R&D level to joint societal reflections, and to communicate these uncertainties across the organisation. This could be considered as a step towards better dealing with unpredictable societal impacts of innovations, which CSR in its current form does not fully support (Pellé & Reber, 2015). However, since reduced uncertainty may not be the only benefit from opening-up, further discussion would be needed about the risk of overlooking other positive effects that deliberation on ethical and social issues can have on project management, personal motivation, or teamwork, among others (cf. Flipse, et al. 2013a).

4.4.2. How to become mutually responsive: Product-responsiveness

Limitation: Fragile stakeholder relations. RRI expressly calls innovators and stakeholders to collectively reflect on the 'right impacts' and purposes of the innovation, and to jointly formulate its goals and directions. However, different understandings about the 'right impacts' can appear as *tensions* in stakeholder relations, limiting the innovators' willingness to expose stakeholders to each other and to the innovation, in fear of risking the R&D project and outcome. Furthermore, the present case studies highlight that stakeholders are not always willing to get involved either. Stakeholders may be *indifferent*, indicating a difficulty to get them committed. At times, also the committed stakeholders may be *reluctant* to become too closely involved, in order to remain objective and neutral. Certain stakeholders may completely *avoid* collaboration with companies due to strategic reasons. Finally, *competitive* relations can emerge among actors with overlapping interests. If we are to open-up the innovation to deliberative participation, such fragilities in stakeholder relations challenge mutual responsiveness from several perspectives.

Tension. It is known in RRI that differing understandings (e.g. values and worldviews) can bring about ambiguous uncertainty, potentially manifesting as tensions between stakeholders (Asveld & Stemerding, 2017). Such tensions characterise the Datashare case from its inception. Datashare's 'privacy friendly data sharing platform' was

intended to simultaneously give control to residents over their own data, and to attract businesses interested in accessing personal data. As Noorman et al. (2017) note, values of privacy and autonomy 'sit uneasy in the societal debate' with those of accessibility, efficiency and profit. Direct contact with stakeholders was perceived as a substantial risk for the continuation of the project, making Datashare cautious to not bring together their business partners with the privacy-CSOs. Datashare's refusal to organise a stakeholder workshop contradicts with RRI's strategies to 'resolve tensions through explication of different perspectives and deliberation' (Noorman et al., 2017). It appears questionable, whether seeking mutual responsiveness in form of e.g. aligned expectations, agreement on courses of action, or even agreeing to disagree, would have been possible without jeopardising the project.

Yet, value tensions were not the sole reason for Datashare to restrict stakeholder involvement. Similarly, while some of the Dutch food companies recognised 'differing visions, goals, motives, sectors and values' as critical issues, they brought out several other factor limiting interactions (Blok et al., 2015). While the attention within RRI has been steered towards value-laden tensions regarding 'right impacts' of innovations, the present case studies brought out a need to draw further attention also to the other fragilities in stakeholder activities, which in some situations can take priority

Indifference. Commitment of stakeholders is an acknowledged requirement for successful collaborations (Blok et al., 2015; Flipse et al., 2014; Nielsen, 2016). Datashare innovators expressed that it was difficult to secure and maintain commitment of some of their business partners, who were not interested in privacy solutions and even less so in users' control of data. As noted by Nielsen (2016), arguments for responsiveness often and misleadingly assume a mutual interest among the actors in the long-term robustness and desirability of the project. In contrast, for Datashare the relations with the indifferent (but strategically important) business partners appeared as 'very fragile and in need of careful nurturing'. As a result, these stakeholders were not involved at early R&D steps, before there was something concrete to demonstrate to them (Noorman et al., 2017).

Reluctance. Further, stakeholders may be reluctant to get involved at certain steps of the innovation, for the sake of remaining neutral and independent. Dutch food companies rarely engaged stakeholders during the middle (product development) phase of R&D, and brought out that most stakeholders also wanted to step out before this phase, and instead take an external critical perspective. (Blok et al., 2015) This was one of the

manifestations of a stark disparity between RRI's ideas and practice in the case study: While it is assumed in RRI that mutual responsiveness leads to sharing responsibility, companies and their stakeholders appeared unanimous in their view that the company alone takes the responsibility for decisions, as the investor for risky, uncertain and costly innovation (Blok et al., 2015).

Avoidance. Moreover, critical stakeholders such as CSOs may have strategic reasons to avoid any collaboration with the private sector, as this could endanger their credibility in the eyes of their sympathisers (Asveld & Stemerding, 2017; Blok & Lemmens, 2015). This may partly explain Datashare's decision to not bring together their business partners and privacy activists. Datashare was also careful not to become too closely associated with either of them, in order to remain credible with both (Noorman et al., 2017).

4.4.2.1. Suggestion: Product-responsiveness

While global challenges are collective concerns, the needs and interests of various stakeholder groups regarding these challenges can differ significantly. As we discussed over process-responsiveness, ambiguous uncertainty indicates a need for *opening-up* the innovation at the R&D-level to the deliberation on goals and purposes, which based on RRI's ideas should involve both innovators and stakeholders. However, the very ambiguities complicate both the *opening-up* and *closing-down* of the innovation, so that during the R&D *throughput* (Blok & Lemmens, 2015), it can be difficult to reach a joint understanding about how to steer the innovation, and to formulate decisions that would be genuinely representative to stakeholder insights. Furthermore, apart from content-related tensions, various other fragilities in stakeholder relations contribute to a discontinuous and asymmetrical stakeholder participation.

Reflecting on the present case studies and previous RRI literature, we suggest to also consider the *output* of the innovation (Blok & Lemmens, 2015), such as a product or service, as one resource to operationalise responsiveness. **Product-responsive innovation**:

- Takes actions to open-up the innovation to stakeholder engagement during R&D, when *process-responsiveness* alerts of such need. Along with the option of closing-down during R&D:

- Considers the option of *open-ended products*, adaptable after the product launch according to diverging values, needs and interests. Approaches that may support in the design of such products include Value-Sensitive Design (VSD) and Adaptive Management.
- Is aware of the various fragilities in stakeholder relations, and considers the option to compensate asymmetries in stakeholder participation by increasing the possibility of choice (adaptability) in the final product. We can hypothesise an example of product-responsiveness based on Datashare's project: Privacy settings of the data sharing platform could be adjustable by resident-users.

We can hypothesise an example of product-responsiveness based on Datashare's project: Privacy settings of the data sharing platform could be adjustable by resident-users, according to how comfortable they are with sharing their information. Acknowledging the option of open-ended products could temperate expectations for aligned stakeholder visions and joint understanding during the R&D process, perhaps encouraging to a more thorough opening-up. Further, product-responsiveness could perhaps compensate some of the asymmetry in stakeholder involvement, by allocating choice also to the less involved stakeholders. Product-responsiveness also makes RRI more explicit about possible roles for adopter-stakeholders, if they are to become mutually responsive with innovators 'with a view to the societal aspects of the innovation' (von Schomberg, 2013). Namely, the product may carry different stories and meanings to different users, who partake in the closing-down by adjusting the product. Thus, also the understanding of responsiveness as a *relation* between innovators and stakeholders becomes more diverse, giving space to more overlapping and 'porous' roles for producers and adopters.

4.4.2.2. Reflecting RRI and practice

Both the Dutch food companies and Datashare were actively involving stakeholders. The case studies capture two distinct approaches, and two problematics, in dealing with *tensions* stemming from deviating stakeholder needs and interests. First, Dutch food companies appear to be driven by the aim of *reducing ambiguity* through stakeholder engagement. They made attempts to align 'expectations, experience and identity' in working towards a joint vision about their innovations. On the other hand, Datashare appeared to *uphold ambiguity* during their stakeholder engagement: they were moulding several separate innovation trajectories, emphasising different aspects of their

product to different stakeholders. To further explore these approaches, it appears useful to follow Stirling's (2008) distinction between *appraisal* and *commitment* in the function of participatory deliberation.

Reducing ambiguity. While Dutch food companies placed importance on the formulation of shared objectives (*closing down commitment*), it remains an open question, to what extent the appraisal was opened-up for diverging discourses and framings at the beginning. What indicates *opening-up appraisal*: The companies had frequent meetings with several stakeholders, in formal and regular settings like project meetings, as well as more informal and irregular such as symposia. They emphasised among others the importance of sharing results, networking through multiple projects, and ad-hoc discussions about signals received from the market. They favoured directness and concreteness in stakeholder interaction, such as: 'this is the product and this could be the package. What is your first impression?'. (Blok et al., 2015) However, the companies and their stakeholders appeared relatively unanimous already from the beginning. As discussed earlier, one foreseeable reason is the low uncertainty: Healthy food criteria are already widely accepted as guidelines for food innovations, and the health issues at stake (e.g. excessive use of salt) have already been broadly discussed in society (Blok et al., 2015). Yet, Blok and colleagues also reported a tendency to overcome uncertainties by the very selection of 'aligned and complementary parties', signalling closing-down appraisal. As one interviewee said, 'I don't really have experience with this [barriers related to different visions and missions among stakeholders] but if this is the case, we just search for another party with which we have a match'. In line with Blok and Lemmens (2015): closing-down appraisal can be a particular risk when the *input* of innovation process is in the global Grand Challenges, like public health. These challenges are 'wicked problems' (cf. Rittel & Webber, 1973), in that they are highly complex and not amenable for definite solutions. This makes agreeing on the problem definition highly challenging and prone to incumbent interests of powerful stakeholders, bringing the responsiveness towards stakeholders highly questionable (Blok & Lemmens, 2015). Further, regarding the food sector, Haen et al. (2015) and Swierstra & te Molder (2012) have remarked that certain concerns seem 'structurally marginalized and barely recognized as legitimate public issues' for deliberation, such as concerns related to naturalness, ownership and control, identity, and lifestyles.

Upholding ambiguity. Against this backdrop, Datashare innovators (Noorman et al., 2017) appear to have taken the challenge of *opening-up appraisal* of the innovation to

differing and also conflicting stakeholder understandings. Their innovation invited tensions from the very outset of its idea (a platform integrating privacy and access), and the assembly of stakeholders, from whom they continuously gathered feedback for their prototype. However, Datashare responded to conflicting understandings by managing multiple innovation trajectories and maintaining their stakeholders separate, 'without confronting them with the tension between the different perspectives on data sharing' (Noorman et al., 2017). The innovators worked as translators between the stakeholders, by 'carefully managing and cultivating the information' obtained via different trajectories. For instance, for their business partners Datashare emphasised a more intimate contact with residents, whereas for privacy activists they highlighted how privacy can be integrated in the product design. On the one hand, this strategy enabled input from stakeholders, who perhaps would have refused to directly collaborate with each other, due to for example strategic reasons. Yet, it remains an open question how the trajectories would be closed-down at the *throughput* of the R&D (*closing-down commitment*), so that the platform would eventually accommodate the conflicting needs and interests. Can Datashare remain responsive to both their business partners and privacy-activists?

Other fragilities in stakeholder relations. In addition to these content-related tensions, both Dutch food companies and Datashare were experiencing other fragilities in stakeholder relations, which further complicated both *input* and *throughput*. As a result, stakeholders were not equally involved and informed in every phase. As per Blok & Lemmens (2015), such information asymmetries during R&D make mutual responsiveness questionable. However, Datashare and the Dutch food companies had management practices for enabling stakeholder collaboration *despite* of various fragilities – even if the outcome was not ideally 'symmetrical'. For instance, when companies faced difficulties in raising some of their stakeholders' interest, they were nevertheless able to involve the more devoted ones (i.e. managing with *indifference*). Further, companies made efforts to further interest their stakeholders with 'socialisation mechanisms', including formal regular project meetings and more informal events like symposia (*indifference*). When stakeholders wished to stay neutral during the middle phase of R&D, companies and stakeholders jointly agreed that the latter step out after the early R&D phase (*reluctance*). Bilateral meetings with strategically divided stakeholders (instead of multi-stakeholder collaboration) enabled their input in the first place (*avoidance*). Companies applied protection mechanisms to secure crucial information, including formal mechanisms like intellectual property management, and semi-formal such as confidentiality agreements

(*competition*). As any formal mechanism has its limitations, they also highlighted the importance of building mutual trust and open organisational culture (*competition*). (Blok et al., 2015; Noorman et al., 2017) Nevertheless, some asymmetry remained despite management practices, further questioning to what extent the appraisals and commitments were representative to societal needs.

To recap: While our suggestion for process-responsiveness stemmed from the challenge that opening-up does not often occur at the R&D level, three further challenges regarding mutual responsiveness appear where such opening-up is (allegedly) ensued. First, innovation is only selectively opened-up for the *input* (indicating *closing-down appraisal*). Second: when *opening-up appraisal* results in conflicting advice, how to reach a *closing-down commitment* during *throughput*? Third, in addition to content-related tensions, coping with other fragilities leaves residual asymmetries, further questioning whether the innovation is representative of societal needs.

Open-ended products. As mutual responsiveness regarding the *input* and *throughput* of the innovation has been already problematized (Blok & Lemmens, 2015), we suggest giving consideration also to the *output* of innovation as a resource for responding to diverging societal needs. That is: to extend the scope of responsiveness into opportunities that innovations uphold once they are 'out in the world' (Robaey & Simons, 2015) after the market launch. Out of their developers' immediate presence, these outputs are not only applied by some of the stakeholders, but possibly also modified further to better fit the context of their use. These post-launch developments can be left overlooked, when innovation is conceptualised as a process starting from the ideation and ending to the launch (e.g. stage-gate model). Does such a conceptualisation also contribute to 'undue privileging' of *closing-down commitment* (Stirling, 2008) in RRI, possibly discouraging from genuinely opening-up the innovation to differences? What opportunities there appear for *open-ended commitments* (Stirling, 2008), acknowledging and even inviting stakeholder responses via post-launch modifications?

It is not far-fetched to envision that Datashare's platform could eventually allow each resident-user to adjust their own privacy settings, according to how comfortable they are with sharing energy consumption data. Also, RRI theory and associated approaches seem to encourage further contemplations on the potential of open-ended products in enhancing responsiveness. For instance, RRI's definition by von Schomberg (2013) calls societal actors and innovators to 'become mutually responsive to each other with a view

to the … innovation process *and its marketable products*' (emphasis added), while van den Hoven (2012) discusses the potential of technologies to spawn new moral choice situations. Concerning different approaches, *value-sensitive design* (Friedman, 1996) has been proposed in RRI for the design of products (e.g. van den Hoven, 2013), and processes (e.g. Dignum et al., 2016), and as such it is a means to operationalise moral choice. Furthermore, *adaptive management* (Armitage et al., 2008) has been linked to RRI as a means to resolve conflicting stakeholders claims, by developing innovation outputs that incorporate multiple trajectories that are switchable or adjustable after launch if unwanted effects appear. An example of this is provided by Asveld and Stemerding (2017), hypothesising an adaptable bio-process as an alternative ending for the Ecover case, able to switch between various feedstocks in case the sustainability of a particular feedstock is later confronted. This could provide a 'way out' from a particular trajectory (e.g. use of particular feedstock), thus avoiding stranding the innovation into a deadlock. Another variation of adaptive design could be the hypothesized output from the Datashare platform, in which different options are left open so that they are applicable in parallel, without excluding some or any of the options.

Finally, incorporating a spectrum of options in the final product could increase resilience in face of asymmetrical stakeholder participation. Although open-ended outputs may not fully compensate the information and power asymmetries, they could at least allocate some more choice also to the less involved stakeholders. In this sense, open-ended outputs may increase 'porosity' of innovation structures (Pavie et al., 2014) against power asymmetries – while broadening discourses from 'who dominates whom' (Pavie et al., 2014) and from 'cultural expectations for proponents and opponents' (Swierstra & Rip, 2007), also towards more many-sided and proactive roles for producers and adopters.

In summary: With product-responsiveness, we suggest to consider also open-ended commitments, in addition to closed-down commitments, as a resource for operationalising responsiveness. Yet, along with the opportunity of increasing users' choice, further discussion should also follow about the trade-off of increasing complexity. Blok and Lemmens (2015) remind that innovation *outputs* uphold radical uncertainty, as our knowledge about the impacts of innovations is limited in general, and especially so when the input is in the Grand Challenges that have no straightforward solutions. Further, van den Hoven et al. (2012) elaborate that when (moral) choice is increased with new technology, we become faced with new side effects and risks, stirring up new value dimensions and again more choice situations (to be tackled with e.g. further technology

development). This considered: How then does increasing choice in the output affect the acceptability, sustainability, or distribution of accountability – and the 'freedom of choice' per se – when individual choices are considered in terms of their collective impacts, or when immediate benefits turn into long-term impacts? Such questions are becoming increasingly tangible, as in sectors like ICT the 'smart and flexible' (customisable) products and services already outnumber single-interface alternatives (Keates, 2015). RRI can foster discussion on both 'right impacts' and risks of such products.

4.4.3. With whom to become mutually responsive? *Pre*sponsiveness

Limitation: No perceived help from society. During early R&D, there were occasions when innovators perceived a need for societal insight, but experienced that stakeholder engagement would not provide tangible contributions for steering the innovation. No *input* either from stakeholders or the innovators themselves was considered meaningful for a fruitful interaction. Datashare innovators expressed that they had not much to get from potential resident-users, regarding privacy concerns and expectations related to their product idea. Simultaneously, the innovators had not much to give either, as the vision for the data sharing platform was not yet clear. (Noorman et al., 2017) The innovators believed that end users have 'latent needs' for privacy, which are difficult to discuss without providing them a clear idea. As one Datashare team member reflected: When people are asked whether they are concerned about their data, they will say no, but in the context of a concrete example they may give a different answer. Further, the team members felt there were *not enough resources* (time) to explain their concept to the resident-users in its current undeveloped state, as Datashare's funders expected the team to proceed quickly (Noorman et al., 2017). Moreover, as Datashare was still reviewing several options for further development of their innovation, Noorman et al. (2017) remark that it may have also been *difficult to identify* relevant stakeholders in the first place.

4.4.3.1. Suggestion: *Pre*sponsiveness

As we discussed over process-responsiveness, indeterminate uncertainties call for stakeholder involvement all along the R&D process, as the 'points of interruption and control' of such uncertainties are highly diffuse over time and space (Lee & Petts, 2013). In private sector, indeterminate uncertainty seems to entail a two-fold challenge: While it is generally problematic to grasp the impacts of an innovation during early-phase R&D (the

Collingridge dilemma), innovators are nevertheless expected to quickly yield tangible results.

From the perspective of mutual responsiveness, the Collingridge dilemma signals an indeterminate uncertainty that all relevant stakeholders may not be known at the time of R&D. Yet, responsiveness as a future-oriented responsibility obliges a receptive attitude towards the needs and desires of others, before deciding what to do (Pellizzoni, 2004). If we are to open-up the innovation to participatory deliberation, who exactly should be involved? Furthermore, how to be responsive to those actors that are potentially affected by the innovation, but are not available at the context of R&D? We suggest a ***pre*sponsive** approach, which:

- Is aware that relevant stakeholders can be unknown and unreachable at a given time of R&D. Among others, stakeholders can be distant in time, place, or sector.
- Takes actions to identify unknown stakeholders and their needs. For example, as part of the experimental approach to innovation.
- Critically reflects on the representativeness of mediators (e.g. interest groups and experts) to stakeholder needs and interests.

*Pre*sponsiveness further elaborates responsiveness as *forward-looking responsibility*: While the first step is to acknowledge that there are uncertainties regarding stakeholders, the receptive attitude should also result in efforts to identify stakeholders and their needs, so that mutual relations could be (at some point) established. However, there is little practical advice derivable from the case studies on how to achieve this. Nevertheless, we have identified *experimentation* as a promising approach in the private sector to address stakeholder-related uncertainties along with other (indeterminate) uncertainty.

4.4.3.2. Reflecting RRI and practice

Datashare's experiences during early R&D echo with the Collingridge dilemma (Collingride 1980). At the time when the concept for Datashare's platform would still be amenable to modifications based on the input from resident-users, there is not enough knowledge for grasping the societal impacts of the innovation. Yet, by the time the concept would be explicit enough to allow diverse societal reflections, it is already locked-in to

certain trajectories so that steering the innovation is difficult, costly and time consuming (e.g. Flipse et al., 2013b; Noorman et al., 2017; Owen et al., 2012) Moreover, the dilemma seemed to be exacerbated by the constant pressure from funders to rapidly produce a proof of demand for the product, driving Datashare to proceed while the long-term picture was not yet clear (Noorman et al., 2017). In the private sector, tight schedules commonly challenge appropriate monitoring of uncertainties (Pavie et al., 2014). Stakeholder interactions are time-consuming, and within a short time it is difficult to have a fruitful exchange of thoughts about the purposes of the innovation (Blok et al., 2015; Lee & Petts, 2013; Noorman et al., 2017). Especially in start-ups, like Datashare, resources are scarce and tightly steered at securing market entry. Hence, start-ups need to carefully balance the claimed benefits of stakeholder engagement with costs and launch delay. Still, start-ups often work with new and emerging technologies, which specifically calls for timely stakeholder discussions. (Scholten & van der Duin, 2015)

Experimentation. Facing pressures for a quick proof of demand, Datashare innovators found themselves looking for 'evidence for something that did not exist yet' (Noorman et al., 2017). In order to work toward this evidence, the team got inspiration from the Lean (start-up) method (cf. Ries, 2011). In a Lean R&D, a prototype or a proposition is modified iteratively, in short cycles of 'validated learning'. Feedback from customers is frequently gathered and applied to further refine the prototype. (Noorman et al. 2017) With this focus, the Lean method resembles the *experimental approach* to innovation, described as continuous testing and learning by means of gradual scaling-up, *while* a technology is introduced in society (e.g. Asveld, 2016; Robaey & Simons, 2015; van de Poel, 2011). Experimentation can be perceived as an effort to manage with the trade-offs resulting from the Collingridge dilemma. First, it is acknowledged that due to uncertainties, meticulous plans are unfeasible in the early steps. Second, the focus is on the discovery and management of uncertainties as they appear along the project: before the innovation is introduced to society in its full scale with possible broad negative impacts. (Asveld, 2016; Van de Poel, 2017).

It has been suggested that experimental approach can support integration of various RRI principles into R&D processes (e.g. Asveld, 2016; Robaey & Simons, 2015.; van de Poel, 2011) – also in the private sector as experimentation yields gradual results along the R&D process, satisfying investors' expectations for a quick evidence (Noorman et al., 2017). Among others, experimentation involves frequent collaboration with societal actors, supporting mutually responsive relations. More specifically: experimentation

explicitly includes the aim of learning (i.e. not only gathering information from stakeholders), it supports exploration of different interpretations on the innovation (opening-up appraisal), and on how values might evolve owing to its introduction (society's responses). Further, stakeholders can be given a chance to step out of the experiment, and to influence on the set up, carrying out, and stopping the experiment (impact on innovation trajectory). However, as van de Poel (2017) also points out, following an experimental method in R&D does not self-evidently lead to a *responsible* conduct of experimentation. From the perspective of mutual responsiveness, in the case studies we can distinguish a challenge regarding unreachable stakeholders, most explicitly in relation to 'mediated presence' (representativeness).

Unreachable stakeholders. Noorman et al. (2017) indicate that further involvement of stakeholder groups in the Lean method may have been limited by a difficulty to identify or specify relevant stakeholders. While it was not explicit to what extent Datashare's innovators were aware or concerned about this limitation, RRI literature identifies multiple reasons for why stakeholders can be 'unreachable'. Based on the background case studies, we distinguished four such circumstances. First, potential stakeholders can be *distant in time* of the R&D: either not yet identified as stakeholders, or belonging to future generations (e.g. Balkema & Pols, 2015). This challenge of responding to future stakeholders is essentially linked to the definition of sustainability (Brundtland, 1987) and intergenerational justice (e.g. Pols & Spahn, 2015). Second, stakeholders may be geographically *distant in place*, and yet being increasingly interconnected via complex supply chains (e.g. Balkema & Pols, 2015), or digital technologies (e.g. Nevejan & Brazier, 2015). Third, and often related to geographical distance, stakeholders with very different backgrounds can be *distant in discourse*, e.g. due to sectoral differences (Blok et al., 2015), different cultural and national settings (Lee & Petts, 2013), or levels of education (Asveld & Stemerding, 2017). For instance, small-farmers in developing countries might be among the most challenging stakeholders to involve in stakeholder interaction (Asveld & Stemerding, 2017; Balkema & Pols, 2015).

Mediated presence. Fourth, in all of the above examples, absent stakeholders can be represented by mediators such as interest groups or experts (e.g. Delgado et al., 2011; Stirling, 2008). For example, Asveld & Stemerding (2017) note that CSOs readily take the role of speaking on behalf of small-farmers, who themselves remain largely unheard. Also, how Datashare team approached the evasive 'latent privacy needs' of resident-users through the Lean method led Noorman and colleagues to contemplate on the 'objectified'

role of this stakeholder group. User preferences were made explicit via 'multiple translation steps', so that the team first consulted external experts, who examined citizens' perceptions about privacy – either directly (interviews) or indirectly (media analyses). In addition, the Datashare team reflected on their own stances to privacy as 'average potential users'. Partly based on these inputs, the team then developed prototypes that were 'validated and refined' with focus groups recruited by an agency. In the meanwhile, Datashare involved particularly interested stakeholder groups more directly, thus giving more weight to some of potential business partners and to an extent to privacy CSOs. Consequently, the resident-users had less impact on the problem-setting: In focus-groups, they were given roles as representatives of certain perspectives on the prototype that already incorporated a limited number of options. (Noorman et al., 2017)

As regards stakeholder representation, Stirling (2008) has noted that indirect expert analysis is not self-evidently less 'conductive to enhanced social agency' than participatory deliberation in every circumstance. Also, it is known to be challenging to arrange a reasonably manageable but not too homogenous amount of design options in practice (Keates, 2015). Nevertheless, the case studies indicate a need to be at least aware that relevant stakeholders may be absent and unknown during R&D. This further attention is justified not least by the tendency to define technological opportunities more clearly for certain stakeholders, while harms remain speculative and farther away, concerning 'as yet anonymous, collective stakeholders' (Swierstra & Rip, 2007). To employ such awareness for enhancing stakeholder representativeness: Asveld and Stemerding (2017) suggest that experimenting with *worldviews* (cf. Hedlund-de Witt, 2013) could have been applied in the Ecover case during early R&D, in order to grasp different perspectives on 'sustainability' already before direct stakeholder involvement. The identified perspectives and tensions regarding a specific topic can be connected to a manageable number of worldviews: a systematically assembled set of coherent value structures shared by a wide range of people in society. If the identified perspectives cover all these *worldviews*, it can be an indication that representation is sufficient (Asveld & Stemerding, 2017; Hedlund-de Wit, 2013). A similar experiment could be hypothesised for Datashare regarding stakeholder perspectives on 'privacy', e.g. as a pre-step for further focus-group work.

In summary: With *pre*sponsiveness, we draw further attention to stakeholders, who despite their current absence may still be affected by, or contributing to, the innovation at its later steps. With the exception of the worldview approach, there is little practical advice in the present case studies for how to identify the needs or identities of

these stakeholders. However, experimental approach appeared as a potential ground in the private sector for further addressing stakeholder-related uncertainties, along with other (indeterminate) uncertainty.

4.5. Conclusions

This paper is an early attempt to further elaborate RRI's concept of responsiveness based on recent practical examinations in private sector R&D. We took a mind-set that tensions between theoretical ideals and complex realities are creative tensions, 'inspiring innovation, experimentation, and future research into alternative options and solutions' (Delgado et al., 2011). Inspired by limitations of mutual responsiveness, we first propose *process-responsiveness*: an elaboration of responsiveness as the *action-element* of RRI that triggers attention to societal uncertainties, which particularly call for R&D-level opening-up. With this proposition, we hope to contribute to the further research on interactions between CSR and R&D, while acknowledging a need for more discussion: reducing uncertainty is hardly the only possible benefit following from opening-up. With *product-responsiveness*, we encourage to consider the option of 'open-ended products' in operationalising responsiveness to diverse societal needs. While product-responsiveness can diversify the understanding of responsiveness as a *relation* between producers and adopters, we also acknowledge needs for further discussions regarding the trade-off of increasing complexity. Finally, we suggest *pre*sponsiveness as an expression of responsiveness as *forward-looking responsibility*, drawing attention to stakeholders whose unavailability at a given moment does not per se make them any less significant. While *pre*sponsiveness largely remains an open challenge, we identify experimentation as one starting point for identifying unavailable stakeholders and their needs.

We cautiously remark that these suggestions are not intended for downplaying the importance of 'ideal-type' mutual responsiveness for responsible innovations, for undermining more refined conceptualisations of mutual responsiveness, or for giving reasons to neglect stakeholder involvement. It is rather our purpose to envision complementary – and perhaps alternative – modes to be responsive to societal needs, which are also not too far-fetched regarding RRI's own theories. Finally, we realise that due to the limited number of available case studies, further research is needed. Our analysis incorporates different cases and contexts, without closely considering the significance of their difference to the identified opportunities and limitations. With this remark, we refer to the diversity in sectors (food, ICT), types of companies (mature, start-up), set-ups for

R&D activities (e.g. tasks of researchers), and stakeholders (research organisations, CSOs, business partners, consumers). More studies will make a more context-specific analysis possible.

References

Armitage, D, M Marschke, R Plummer (2008). Adaptive co-management and the paradox of learning. *Glob Environ Chang*. 18(1): 86–98

Asveld, L. 2016. The need for governance by experimentation: The case of biofuels. *Sci Eng Ethics* 22(3): 815–830

Asveld, L. & Stemerding, D., 2017. Social learning in the bioeconomy: The Ecover case. In: *New perspectives on technology in society: Experimentation beyond the laboratory.* s.l.:Routledge, pp. 103-124.

Balkema, A., Pols, A. (2015). Biofuels: Sustainable innovation or gold rush? Identifying responsibilities for biofuel innovations. In B. J. Koops, I. Oosterlaken, H. Romijn, T. Swierstra, J. van den Hoven (eds.), *Responsible innovation 2: Concepts, approaches, and applications* (pp. 283–303). Dordrecht: Springer International Publishing.

Blok, V. 2014. Look who's talking: Responsible innovation, the paradox of dialogue and the voice of the other in communication and negotiation processes. *Journal of Responsible Innovation* 1(2): 171–190

Blok, V., Lemmens, P. (2015). The emerging concept of responsible innovation. Three reasons why it is questionable and calls for a radical transformation of the concept of innovation. Responsible Innovation 2: Concepts, Approaches, and Applications, 19–35.

Blok, V, L Hoffmans, EFM Wubben (2015). Stakeholder engagement for responsible innovation in the private sector: Critical issues and management practices. *Journal on Chain and Network Science* 15(2): 147–164.

Blok, V., Tempels, T., Pietersma, E. & Jansen, L. (2017). Exploring Ethical Decision Making in Responsible Innovation: the case of innovations for healthy food. In L. Asveld, R. van Dam-Mieras, T. Swierstra, S. Lavrijssen, K. Linse & J. van den Hoven (eds.), *Responsible Innovation 3: A European Agenda?*, (pp. 231-249). Springer, Dordrecht, The Netherlands.

Brundtland, GH. (1987) *Our common future.* World commission on environment and development. Oxford: Oxford University Press.

Cooper, R. (1990) Stage-gate systems: A new tool for managing new products. Business Horizons 3(33): 44–55.

Delgado, A, KL Kjølberg, F Wickson. 2011. Public engagement coming of age: From theory to practice in STS encounters with nanotechnology. *Public Underst Sci* 20(6): 826–845.

Dignum, M, A Correlje, E Cuppen, U Pesch, B Taebi. 2016. Contested technologies and Design for Values: The case of shale gas. *Sci Eng Ethics* 22(4): 1171–1191.

Flipse, SM, MCA van der Sanden, P Osseweijer (2013a). Midstream modulation in biotechnology industry: Redefining what is "part of the job" of researchers in industry. Sci Eng Ethics 19(3): 1141–1164.

Flipse, SM, MCA van der Sanden, P Osseweijer (2013b). The why and how of enabling the integration of social and ethical aspects in Research and Development. *Sci Eng Ethics* 19(3): 703–725.

Flipse, SM, MCAVD Sanden, M Radstake, JHD Winde, P Osseweijer (2014). The DNA of socially responsible innovation. *EMBO Rep* 15(2): 134–137.

Flipse, SM, KH Van Dam, J Stragier, TJC Oude Vrielink, MCA Van der Sanden (2015). Operationalizing responsible research & innovation in industry through decision support in innovation practice. *Journal on Chain and Network Science* 15(2): 135–146.

Friedman, B. (1996). Value-Sensitive Design. *Interactions* 3(6): 17–23.

Ganzevles, J, R van Est. (2012). PACITA: Collaborative project on mobilisation and mutual learning actions in European Parliamenary technology assessment – Deliverable 2.2. TA Practices in Europe Rathenau Instituut, 238. Hague: Rathenau Instituut.

Haen, D., Sneijder, P., te Molder, H., Swierstra, T. (2015). Natural food: Organising "responsiveness" in responsible innovation of food technology. In B. J. Koops, I. Oosterlaken, H. Romijn, T.

Swierstra, J. van den Hoven (Eds.), *Responsible innovation 2: Concepts, approaches, and applications* (pp. 161–181). Dordrecht: Springer International Publishing.

Hedlund-de Witt, A. (2013). *Worldviews and the transformation to sustainable societies: An exploration of the cultural and psychological dimensions of our global environmental challenges*. Ph.D. Thesis. Amsterdam: VU University.

Iatridis, K, D Schroeder (2016). *Research and innovation in industry: The case for corporate responsibility tools*: Springer.

Jones, TM. (1991). Ethical decision making by individuals in organizations : An issue-contingent model. *Acad Manag Rev* 16(2): 366–395.

Keates, S. (2015). Design for the Value of inclusiveness. In J. van den Hoven, P. E. Vermaas, I. Van de Poel (Eds.), *Handbook of ethics, values, and technological design* (pp. 383–402). Dordrecht: Springer.

Koops, B. J. (2015). The concepts, approaches, and applications of responsible innovations: An introduction. In B. J. Koops, I. Oosterlaken, H. Romijn, T. Swierstra, J. van den Hoven (eds), *Responsible innovation 2: Concepts, approaches, and applications* (pp. 1–15). Dordrecht: Springer International Publishing.

Landeweerd, L. (2017). Europe by nature: RRI in a blurred European governance stucture. Retrieved February 7, 2016, from https://www.researchgate.net/publication/313419598_Europe_by_Nature.

Lee, R. G., & Petts, J. (2013). Adaptive governance for responsible innovation. In: R. Owen., J. Bessant & M. Heintz (Eds.) *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society* (pp. 143–164): London: Wiley.

Nevejan, C., Brazier, F. (2015). Design for the Value of presence. In J. van den Hoven, P. E. Vermaas, I. Van de Poel, *Handbook of ethics, values, and technological design: Sources, theory, values and application domains* (pp. 403–430). Dordrecht: Springer.

Nielsen, M. V. (2016). The concept of responsiveness in the governance of research and innovation. Science and Public Policy, 43(6): 831–839.

Noorman, M., Swierstra, T. & Zandbergen, D. (2017). Questioning the normative core of RI: the challenges posed to stakeholder engagement in a corporate setting. In L. Asveld, R. van Dam-Mieras, T. Swierstra, S. Lavrijssen, K. Linse & J. van den Hoven (eds.), *Responsible Innovation 3: A European Agenda?,* (pp. 231-249). Springer, Dordrecht, The Netherlands.

Owen, R, P Macnaghten, J Stilgoe (2012). Responsible research and innovation: From science in society to science for society, with society. *Sci Public Policy* 39(6): 751–760.

Owen, R., Stilgoe, J., Macnaghten, P., Gorman, M., Fisher, E., Guston, D. (2013). A framework for responsible innovation. In: R. Owen., J. Bessant & M. Heintz (Eds.) *Responsible innovation: Managing the responsible emergence of science and innovation in society* (pp. 143 – 164): London: Wiley.

Pavie, X, V Scholten, D Carthy (2014) *Responsible innovation: From concept to practice*: World Scientific Publishing Company.

Pellé, S, B Reber (2015) Responsible innovation in the light of moral responsibility. *Journal on Chain and Network Science* 15(2): 107–117

Pellizzoni, L (2004). Responsibility and environmental governance. *Environmental Politics* 13(3): 541–565.

Pols, A., & Spahn, A. (2015). Design for the Values of Democracy and Justice. In J. van den Hoven, P. E. Vermaas, I. Van de Poel (Eds.) *Handbook of Ethics,Values, and Technological Design: Sources, Theory, Values and Application Domains* (pp. 335–363): Dordrecht: Springer.

Ries, E. (2011). *How today's entrepreneurs use continuous innovation to create radically successful businesses. In The lean startup*. New York: Crown Business Publishing.

Rittel, HWJ, MM Webber. (1973). Dilemmas in a general theory of planning. Policy Sci 4(2): 155–169.

Robaey, Z., Simons, A. (2015). Responsible management of social experiments: Challenges for policymaking. In B. J. Koops, I. Oosterlaken, H. Romijn, T. Swierstra, J. van den Hoven (Eds.) *Responsible innovation 2: Concepts, approaches, and applications* (pp. 87–104). Dordrecht: Springer.

Scholten, VE, PA van der Duin. (2015). Responsible innovation among academic spin-offs: How responsible practices help developing absorptive capacity. *Journal on Chain and Network Science* 15(2): 165–179

Stilgoe, J., Owen, R., Macnaghten, P. (2013). Developing a framework for responsible innovation. Res Policy, 42, 1568–1580.

Stirling, A. (2008). "opening up" and "closing down": Power, participation, and pluralism in the social appraisal of technology. *Sci Technol Hum Values* 33(2): 262–294.

Swierstra, T, A Rip. (2007). Nano-ethics as NEST-ethics: Patterns of moral argumentation about new and emerging science and technology. NanoEthics 1(1): 3–20.

Swierstra, T, H te Molder. (2012). Risk and soft impacts, Epistemology, Decision Theory, Ethics, and Social Implications of Risk. In S Roeser, R Hillerbrand, P Sandin, M Peterson (Eds.) *Handbook of Risk Theory*, 1049–1066: Springer.

van de Poel, I. (2011). Nuclear energy as a social experiment. Ethics, Policy & Environment 14(3): 285–290.

van de Poel, I. (2017). Society as a laboratory to experiment with new technologies. In D. Bowman, E. Stokes, A. Rip (Eds.) *Embedding new technologies into society: A regulatory, ethical and societal perspective*. (pp. 61–68). Singapore: Pan Stanford Publishing.

van den Hoven, J, GJ Lokhorst, I Van de Poel. (2012). Engineering and the problem of moral overload. Sci Eng Ethics 18(1): 143–155.

van den Hoven, J. (2013). Value sensitive design and responsible innovation. In: R. Owen., J. Bessant & M. Heintz (Eds.) *Responsible innovation: Managing the responsible emergence of science and innovation in society* (pp. 75 – 84): London: Wiley.

Von Schomberg, R. (2013). A vision of responsible research and innovation. In: R. Owen., J. Bessant & M. Heintz (Eds.) *Responsible innovation: Managing the responsible emergence of science and innovation in society* (pp. 51 – 74): London: Wiley.

Zwart, H, L Landeweerd, A van Rooij. (2014). Adapt or perish? Assessing the recent shift in the European research funding arena from “ELSA” to “RRI.”. Life Sciences Society and Policy 10(1): 11.

Chapter 5

Conclusions

This doctoral thesis has investigated the concept of responsibility in the context of industrial research and innovation. The *societal problem* addressed in this thesis is the radical uncertainty of innovation, being unpredictable activity with complex and sometimes ambiguous consequences in society. The addressed *academic problem* is the lack of an innovation governance approach for management of responsibilities in the uncertain R&I environment.

The thesis set out by formulating a framework for responsibility that incorporates approaches on how to work and make decisions under uncertainty. The framework was formulated by building on the current literature of RRI. The key background literature consists of those studies that develop RRI as meta-responsibility approach, providing an outlook for R&I to manage their responsibilities.

The framework's practical applicability and relevance was explored by case-studying R&I projects in the private sector (Chapters 2–4). The results of these research studies provide answers to the principal research question of this thesis: *How can different elements of responsibility be carried out in industrial R&I?*

Chapter 5.1 will revisit the idea of responsible innovation in light of meta-responsibility and its elements, summarizing what the implementation of responsible innovation would require from R&I practitioners and their collaborators. Chapter 5.2 will present the meta-responsibility mapping approach for R&I projects and consortia to identify, discuss and then align their responsibilities as part of their decision making, planning and problem-solving activities. Chapter 5.3 will recapitulate the contributions of this thesis to the key theories and concepts of responsible innovation discussed in the previous chapters. Further, Chapter 5.3 will reflect on the implications that the findings of this thesis can have on the practice and management of industrial R&I, on corporate governance, and at the level of value chains. Finally, Chapter 5.4 reflects on limitations of this thesis and suggests topics for further research.

5.1. Responsible innovation in light of meta-responsibility

This thesis has developed a meta-responsibility framework in view of the earlier developments in innovation governance, which were reviewed in the introductory Chapter 1. In Chapter 1, it was summarized that the meta-responsibility framework needs to i) acknowledge various elements and interpretations of responsibility), ii) enable

coordination and management of those elements in R&I, and iii) acknowledge characteristics of industrial R&I.

As starting point, the responsibility framework by Pellizzoni (2004) was chosen that divides responsibility into the elements of *care*, *liability*, *accountability*, and *responsiveness*. The framework was modified to become more attentive to R&I as highly uncertain and future-oriented environment. By case-studying bioeconomic R&I projects, it was found that these responsibility elements not only co-exist in R&I, but appear in relation to each other, as different aspects to a particular choice situation.

In summary: Responsible innovation requires coordination of several co-existing strategies to manage uncertainty of innovation. The presented meta-responsibility framework adheres to this requirement. The strategies to manage with uncertainty are presented under the four responsibility elements of *care* (values and norms as guideline), *liability* (legal/formal requirements as guideline), *accountability* (evaluation of impacts) and *responsiveness* (learning-whilst-doing). Next, it will be summarized what the implementation of these elements demands of R&I practitioners, and who in the R&I networks should take part in their implementation, for innovation to be considered responsible.

Care is a *forward-looking* element of "taking responsibility" for future, with an *assertive* stance to uncertainty in the sense that it justifies actions by following generally shared norms and values of society. To undertake care asks an attitude of looking beyond one's immediate duties and jurisdiction, into societal goals and principles that can be addressed by "doing good" with innovation. As a forward-looking element, care involves taking "collective stewardship" (van de Poel & Sand, 2018) beyond role-related responsibilities, portraying responsibility as an obligation of everyone. Accordingly, care-motivated actions appear at many levels: employee-level (moral motivations), project-level (strategic sustainability guidelines), consortium-level (shared guidelines) and stakeholder-level (societal norms providing a point of confluence).

Liability is a *backward-looking* element of "holding responsible" for actions, having a strong sanctioning power to oblige individuals and institutions. Liability is *assertive* in face of uncertainty: what is right is deemed in legislation, regulations, and contracts. In R&I, liability prescribes actions of fulfilling obligatory requirements (e.g. compliance with environmental/safety legislation) but it is also involved in building R&I networks

(partnership agreements), and in advancing economic goals (with help of legal frameworks, e.g., patenting). At value-chain level, regulators and policymakers were identified as strong enablers of sustainable transition owing to their authority to impose and monitor liabilities over entire manufacturing chains.

Accountability is a *backward-looking* element of "holding responsible" for impacts of actions. Undertaking accountability requires continuous focus on impacts of R&I: before an action (anticipatory methods), during that action (monitoring), and after that action (reporting). Accountability implies a *receptive* stance to uncertainty: being conscious about limitedness of knowledge, and weighing options based on the best available knowledge at the time. Weighing proceeding options under uncertainty demands specialized skills and field expertise, making accountability a typical occupational role-related responsibility. In multi-actor R&I, setting clear accountabilities facilitates transfer of material ownership between value chain participants. Having precise quality requirements and traceable records, as to what is supplied to whom, can be construed as one strategy against the "problem of many hands" in responsible innovation. At value-chain level, R&I funding bodies were identified as enablers of sustainable transition, having authority to impose accountability for fulfilling societal goals as a condition for funding.

Responsiveness is an element that resonates strongly with R&I as an opportunity-driven yet uncertain working environment. As a *forward-looking* and *receptive* element, responsiveness supports taking responsibility for improving the current state-of-affairs despite considerable uncertainties (epistemological, indeterminate, ambiguous). Of R&I practitioners, responsiveness demands openness to the possibility that the means to reach their goals, and even the goals themselves, may change drastically, when more knowledge is acquired as the innovation becomes gradually introduced with society. In line, responsiveness prescribes actions of constant adjustment: learning-by-doing, experimentation, iteration, and acceptance of risk. As a forward-looking element, responsive attitude can also cross over role-specific responsibilities and take collective forms, e.g. as joint problem-solving activities in R&I consortia.

Especially at early R&I stages, responsible innovation is characteristically *responsive innovation* of working adaptively under radical uncertainty. Along this line of thought, responsiveness encapsulates a particular and essential role that R&I teams and units play in terms of corporate responsibility as the "responsive units" of companies. Thus

far, the role of responsiveness in linking R&I with corporate responsibility has not been clearly articulated in RRI, and it has remaining indistinct also in the literature of CSR.

At later stages of innovation, the adaptive ways of working meet their limitation in the Collingridge dilemma (1980): the more the innovation scales up and matures, the more unchangeable its features become. Yet, while uncertainty becomes reduced at later R&I stages it is never fully eradicated. A responsive mindset is required at all stages of R&I to deal with unexpected occurrences.

Finally, this thesis re-examined the idea of *mutual responsiveness.* As initially defined in RRI, responsible innovation involves stakeholder interaction through which innovators and stakeholder become mutually responsive to each other's viewpoints. This thesis identified several limitations of mutual responsiveness in practical R&I, and provided insights into "alternative" modes to become responsive to societal needs. Particularly, these involve rethinking the role of usage-stage and consumers in emerging modes of production, such as circular economy. The so-called *product-responsiveness* is proposed in Chapter 4 for designing "open-ended products" that are adaptable after launch by consumer choice and preferences. Further, in Chapter 3 the option of monitoring long-term impacts of innovation during usage was brought out. It must be noted that applicability of such options depends on the industrial sector, and further, that open-ended products raise questions about user safety when unexpected consequences (residual risks) are outsourced to consumers instead of being addressed during development stage.

5.2. How to carry out responsibilities with help of meta-responsibility approach

The **meta-responsibility mapping** approach was developed over the course of this thesis to support that different aspects of responsibility become considered in R&I work. It has been designed in view of the interrelated nature of responsibilities. Instead of merely inventorying different elements of responsibility, meta-responsibility mapping is purposed for landscaping dynamics – tensions, gaps, synergies – between the elements.

The meta-responsibility map introduces a set of *guiding questions*, designed to trigger discussion about the responsibilities at stake. Thereafter, the guiding questions support selection of *practices and tools* to address these in practical R&I work. The guiding questions are directed on the one hand to support R&I teams and consortia in choice

situations such as goal setting and problem-solving. On the other hand, the guiding questions can facilitate stakeholder discussions among e.g. innovators, regulators, and potential end users.

The meta-responsibility map is presented in Figure 5.1. The guiding questions numbered in Fig. 5.1 are explicated in Table 5.1.

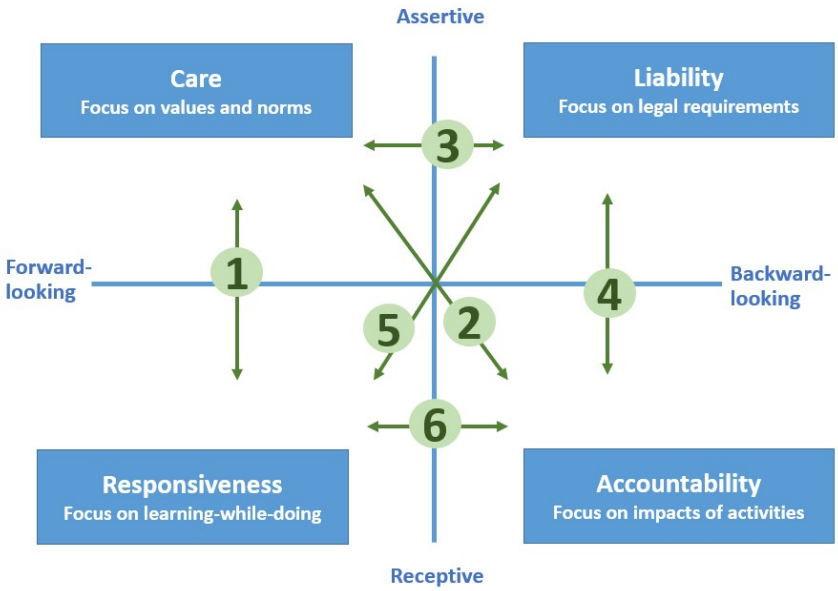

Figure 5.1. Meta-responsibility map for R&I.

Table 5.1. Guiding questions according to the corresponding responsibility elements at stake, as numbered in Figure 5.1.

# **Elements at stake**	**Theme**	**Guiding question for R&I teams**	**Guiding questions for stakeholder dialogue**
1. Care – Responsiveness	Ensuring that goals and criteria of a good innovation are similarly understood.	Has enough been done to assure that the aim of innovation is societally acceptable and of demand?	Are societal goals (e.g., sustainability, safety) similarly understood?
2. Care – Accountability	Ensuring that the impact footprint is according to the initial values.	Are the expected outcomes in line with our values?	Are the expected outcomes in line with your values?
3. Care – Liability	Ensuring that normative and regulatory/ contractual requirements are aligned.	Are the contracts in line with our norms, values and goals?	Do regulations comply with the norms, values and goals?
4. Liability – Accountability	Keeping formal requirements up-to-date with actual risks and opportunities of innovation.	Do contracts sufficiently cover the possible impacts of innovation?	Do regulations properly grasp the opportunities and risks of innovation?
5. Liability – Responsiveness	Enabling fair and viable sustainable transition.	How to accelerate sectoral (sustainable) transition while also safeguarding one's own competitive edge in it?	Do regulations enable a level playing field for established and emerging activities?
6. Accountability - Responsiveness	Maintaining balance between innovation and precaution.	Should we move on and accept the remaining risks, or should we wait until more knowledge is gained?	What risks are afforded to take, and where is precaution non-negotiable?

5.2.1. Guiding questions to reflect on responsibilities

The guiding questions are designed based on what issues the theoretical formulations of responsibility were able to capture in the studied R&I case projects. The questions provide heuristic starting points for future R&I projects and consortia to identify and reflect on their responsibilities for the process, outcomes and impacts of innovation. How the guiding questions can support responsible innovation in R&I projects is summarized below.

Supporting R&I teams in decision-making under uncertainty. With meta-responsibility, various options for how to operate under uncertainty come into consideration in decision-making. The elements of responsibility incorporate different strategies with regard to uncertainty: following normative guidelines (*care*), focusing on regulatory and contractual criteria (*liability*), (pre-)evaluation of impacts (*accountability*), and learning-whilst-doing (*responsiveness*). For instance, the guiding question about tolerable level of risk (Question 6) can assist R&I practitioners in balancing between expectations to be *responsive* to opportunities (to accept the limitedness of knowledge and move on) and to take *accountability* in light of risks (to wait and gain more knowledge before moving on). This deliberation on responsibilities also links meta-responsibility with RRI's principle of *reflexivity*.

Considering the level of uncertainty when choosing actions. Some innovations are surrounded by more uncertainty than others. Incremental innovations, such as small improvements on existing solutions, exhibit less epistemic and indeterminate uncertainty than those of radical novelty. Also, some innovations enjoy a broader societal consensus (lower ambiguity) than others. Chapter 4, with the so-called *process-responsiveness*, suggests keeping an eye on situations of high normative uncertainty that particularly require broader stakeholder involvement, ethical reflections, and other activities that investigate societal acceptability as part of R&I work. When less uncertainty is observed, normative anchor points (e.g., on sustainability, safety) may provide sufficient support for R&I as strategy-level guideline (similar to Blok et al, 2017). Accordingly: Guiding question 1, staging an interplay between care ("going good") and responsiveness ("learning what is good"), is posed to steer R&I's resources depending on the level of normative uncertainty.

Anticipating future choice situations and responsibilities. When discussed during early R&I stage, the guiding questions could prepare R&I practitioners for future choice

situations. This likens meta-responsibility to RRI's principle of *anticipation*. In the early-phase Bio2X, the interviewing triggered respondents to reflect on their concerns, some of which became intensively discussed during later stages when crucial choices regarding commercialization were being made. With meta-responsibility, these questions could be explored more systematically already at early-phase R&I, to pave way for the decision-making at later stages. In addition, many of Bio2X's early-stage practices (often forward-looking) became understandable through the meta-responsibility lens as anticipation of commercial-stage responsibilities (increasingly backward-looking). For instance, a tentative pre-LCA study during early R&I appears as anticipation of *accountability*, at a point in time where full LCA is not yet reasonable due to knowledge scarcity. This exemplifies, how meta-responsibility could help to bridge early-stage activities of "*research*" (reducing epistemological uncertainty) with later-stage activities of *"innovation"* with increasing accountabilities and liabilities.

Aligning different interests and agendas related to the innovation. Unawareness of various responsibilities is hardly the only obstacle to living up to one's responsibilities. Responsibilities are prioritized over each other, unintentionally but also deliberately. For instance, the target of profit generation constitutes the prime role-*accountability* in the private sector, in relation to which other aspirations need to be acclimatized, also in the R&I context. The goals that go beyond sole profit orientation often appear in form of *care*, therefore lacking the sanctioning power of backward-looking responsibilities as well as clearly ascribed authorities and subjects. This implies a risk that broader societal goals remain a responsibility of no-one and a dead letter in strategies. Meta-responsibility, by bringing different goals, interests and agendas under the shared terminology of responsibility, can support in coordination of business-related and societal goals of innovation. The meta-responsibility map (Fig. 5.1) parallels care-motivated goals with backward-looking elements of "holding responsible". It invokes reflection whether the normative and contractual/regulatory guidelines are in line (Question 3), and whether the expected impacts of innovation are in line with normative goals (Question 2). With this respect, meta-responsibility makes RRI more equipped to support alignment of business-related and broader societal goals.

Fostering reflection on responsibilities in evolving value chains. The guiding questions in Fig. 5.1 capture several themes that address distribution of responsibility in value chains. These questions can be used to facilitate interactions between industrial innovators, regulators and policymakers, and representatives of civil society such as end

users. The addressable themes include, for instance: acceptability of innovations in face of public values (Q(uestion) 1) and regulations (Q3), impact footprint in light of initial societal goals (Q2) and what is required by law (Q4), how risks and benefits of novel solutions ought to be balanced (Q6), and whether regulatory frameworks are supportive to novel solutions (Q5). With the meta-responsibility approach, the academic community of RRI could have a facilitator role in these interactions. These questions can shed light on sustainability and ethical issues not only within bio-based value chains, but also in other debated contexts such as clothing industry, or rare metal sourcing for electric gadgets and cars.

Addressing the "Problem of Many Hands" in R&I consortia by facilitating allocation of responsibilities. An inventory of subjects, objects, authorities, norms and capacities can be combined with the meta-responsibility framework, as was done in Chapter 3. For R&I consortia, this analysis provides a set of recommendations that support allocation of responsibilities between the actors, reduce dilution of responsibilities, and therefore, address the "Problem of Many Hands" (Thompson, 1980; van de Poel, et al., 2012). An example of how such recommendations could open up from the inventory can be provided: i) In cases where a subject is identified can be clearly "held responsible" (accountable, liable) for an object, it should be verified that these role responsibilities are clear to everyone in the consortium. In cases where an object is identified but the subject (and authority) of that object is not fully clear, it needs to be investigated whether ii) new accountabilities (or liabilities) can be established, or iii) if collective actions of "taking responsibility" (care, responsiveness) is a more feasible option, such as agreeing on shared principles or strategic guidelines. Finally, iv) there needs to be openness and communication about residual uncertainty regarding impacts and dependencies that remain still unknown. *Responsive* practices for how to manage upcoming unexpected occurrences should be jointly agreed.

In the above example, a conscientious difference is made between situations where causal connection between a subject and an object is observable, and where the complexity of causes and outcomes impedes establishing such connection. In the former case, backward-looking responsibilities can be appointed to avoid the many hands' problem, whereas as in the latter the forward-looking attitude (care, responsiveness) can provide ways forward. Making this difference is necessary in responsible innovation, in order to avoid a situation that forward-looking, collective responsibility is evoked for the reason of escaping individual accountability for negative impacts. While the forward-looking attitude can encourage acting under high uncertainty and causal complexity, it

lacks the exactness of having clear subjects and authorities, and is therefore prone to "collective irresponsibility" and dilution of responsibility.

5.3. Implications on theory and practice

This section provides a synthesis on how the systematic approach on responsibility presented in this thesis can contribute to the key theories and concepts of RRI. Next, it reflects on the implications that the findings of this research could have on the practice and management of R&I, as well as on the enablers, controllers and collaborators of R&I at the value chain level.

5.3.1. Contributions to theory

As its key contribution, this doctoral thesis introduced a framework of responsibility for the R&I context. An earlier framework, formulated by Pellizzoni (2004) in the context of environmental governance, was purposed for the R&I context by elaborating its elements from the viewpoint of addressing uncertainty (Figure 2.1). Further, based on case-studying actual R&I projects, the framework was transformed from being a static outlook on responsibility elements into a tool of meta-responsibility that enables exploring dynamics between these elements as co-existing and sometimes conflicting mindsets (Figure 5.1).

With its organized approach to the notion of responsibility, this thesis contributes to RRI by developing it into a more *responsible* research and innovation approach. Many concepts and discussions in the extant RRI literature, while being closely linked to responsibility, have not been adequately explicated with the terminology of responsibility. Being explicit in terms of how RRI's approaches address different aspects of responsibility in innovation can make RRI theoretically more coherent as well as practically more understandable. What follows is a summary of the RRI concepts and discourses discussed in this thesis, through the frame of meta-responsibility.

Prevalent discourses and contradictions within RRI underline different approaches to responsibility. The discourse between a *normative and procedural* approach (von Schomberg, 2013; Owen et al., 2013; Blok et al., 2017) represents distinct attempts to undertake responsibility in uncertain situations: by adhering to shared normative basis (care), and by critically reflecting on the adequacy of that basis in light of

emerging opportunities and risks (responsiveness). Similarly, regarding *precautionary* and *innovation principles* (e.g., Dreyer et al., 2017): the former emphasizes accountability while the latter signals responsiveness. Finally, a few scholars have brought up the complexity in striking a balance between opening up the innovation to societal appraisal, and restricting the information flow to gain competitive advantage and to move on with innovation (e.g., Stirling, 2008; Blok & Lemmens, 2015). In responsibility terminology, there appears an interplay between responsiveness (openness; attempts to be responsible for societal demands) and liability (closure; responsibility for safeguarding corporate assets and resources). With meta-responsibility, these and similar dichotomies become distinct and complementary approaches to practice responsibility in R&I, and therefore objects of deliberation in decision making.

Key concepts of RRI, when explicated through meta-responsibility, become more closely linked to the management of responsibilities in R&I. Regarding the elements of the procedural approach to responsible innovation (Stilgoe et al., 2013), meta-responsibility further elaborates how *anticipation*, *reflexivity*, *inclusion* and *responsiveness* can be operationalized to support responsible R&I. Anticipation links to thinking ahead the emergent responsibilities at early R&I stage, to develop preparedness to transform from the early *research* phase (more forward-looking) to the pre-commercial phases of *innovation* (with increasing backward-looking responsibilities). Reflexivity is required to invoke a receptive stance to uncertainty, alongside assertive attitudes, for developing a critical eye for situations where scrutiny of the normative and contractual setup is required. As implication, the link between anticipatory and reflective practices with responsible (as well as successful) innovation becomes better understandable.

Regarding *inclusion*: The earlier work on meta-responsibility has already emphasized the inherently networked nature of responsibility, followed by endeavours of mapping actors in responsibility networks (who, for what, to whom; i.e. subjects, objects, authorities) (Stahl, 2013; Timmermans et al., 2017; Ceicyte & Petraite, 2018). The present doctoral thesis, by opening up the concept of responsibility into four elements, contributes to the previous studies by enabling explorations as to “in what sense” the actors in R&I networks and value chains can be considered responsible for the processes, outcomes and impacts of innovation. Moreover, the *capacity* (or response-ability) of the identified actors to actually undertake responsibility in multi-actor settings was considered in Chapter 3. Furthermore, Chapter 4 identified limitations of inclusion owing to sensitivities in stakeholder relations in the industrial R&I context.

As implication: RRI's demands for an inclusive R&I, which may seem oversimplified and unrealistic in light of R&I practice, are enriched by opening up the different aspects of how responsibility can (or cannot) become appointed and practiced in multi-actor settings. Furthermore, awareness of the co-existence of various responsibilities in R&I (to societal wellbeing, to shareowners, to contractual liabilities, etc.) makes RRI more equipped to address the perceived asymmetries, limitations and sensitivities in stakeholder relations.

The concept of *responsiveness* was adopted from Pellizzoni's framework (2004) into early RRI, where it became remarkably disconnected from its initial context of being *one aspect* of responsibility (Fig. 2.1). The present doctoral thesis recreates this connection. It was emphasized that any demand for R&I to be "responsive" to broader societal needs (which is often promoted in RRI), in order to be viable, needs to acknowledge the many pre-existing responsibilities within R&I projects that seem more immediate and are backed-up by effective sanctions (as well as rewards). That said, responsiveness as the forward-looking and receptive approach to uncertainty and unexplored opportunities appears pivotal for the success of R&I. The role of R&I as a specific and irreplaceable component of corporate responsibility becomes explicated and justified by its responsiveness to forthcoming challenges and prospects.

Finally, this work has identified preconditions under which the demanding ideal of *co-responsibility* can be operationalized in multi-actor R&I settings. As summarized in section 5.2, making the distinction between forward- and backward-looking responsibility is a prerequisite for co-responsibility in R&I networks and consortia, so that the forward-looking collective attitudes do not become misused for diluting individual accountabilities.

5.3.2. Management and policy implications

Implications on R&I practice and management. The presented aspects of responsibility (Fig. 2.1) can be perceived as distinct mindsets, or strategies, to take responsibility in face of uncertainty. A central argument is that these mindsets should co-exist in R&I, for innovation to be considered responsible. What follows is a reflection of the implications of this requirement on R&I employee and management level.

Based on several years' work in the Bio2X project, a general observation can be drawn that R&I practitioners, as any individuals, react to uncertainty in various ways. While uncertainty can trigger concerns, confusion and anxiety, others may find the unknown and

unexplored to be a source of motivation and commitment. Similarly, while some respond to unclarity with rigorous planning, others are inclined to ad hoc responses in unexpected situations. Such tendencies can also co-exist within individuals, with their precedence varying over time, the project phase, and general circumstances in life. Understanding and acknowledging individual viewpoints and ways of working through the meta-responsibility frame – as distinct ways to cope with uncertainty – could be a source of motivation, self-confidence, and perhaps professional development for R&I practitioners.

For R&I project management, the meta-responsibility frame could provide a "checkpoint" for whether the different aspects of responsible innovation are represented in the project among its members. To illustrate: a successful conduct of any project requires finding a balance between the determination to accomplish what has been agreed (assertiveness) and a promptness to question the reasoning behind those initial targets (receptiveness). Similarly, those who readily speak out concerns related to risky consequences and sources of failure (backward-looking) need to be heard, as well as those who see opportunities first and trust that challenges can be overcome (forward-looking). A good representation of different standpoints remediates against blind spots, but also against certain mentalities overruling others.

Management practices and tools to implement responsibilities in R&I. Besides supporting at the level of mindsets, meta-responsibility can further assist R&I practitioners and managers by pinpointing practical methods and tools to implement the responsibilities at stake in R&I work. Plenty of methods to undertake responsibilities were in use in Bio2X and BC, and familiar in industrial R&I in general. By linking the choice of methods with the guiding questions (Table 5.1), meta-responsibility supports context-sensitive application of management practices throughout R&I and its decision making.

The case studies conducted within this thesis exemplify two alternative ways to establish a toolbox of methods and practices. First: tools can be arranged based on the identified tensions between aspects of responsibility (see Tables 3–5 in Chapter 2). In this arrangement, some practices address particular elements of responsibility (such as prototyping for responsiveness, or LCA for accountability), while others mediate in between (pre-LCA as anticipation of accountability). Second: distinction can be made between practices that are within reach of individual R&I projects, those implementable by other value chain members (e.g., policymakers, end users), and those requiring contribution of several members together (see Tables 2–3 in Chapter 3).

Implications on corporate strategy and governance. The findings of this study speak for the importance of communication between the corporate strategy level (setting targets for R&I, e.g., through sustainability goals) and the procedural R&I (exploring opportunities for commercial activity based on those targets). As explicated in Chapter 1, novel solutions generate complex interactions with society and environment, and R&I units as developers of those solutions stand in the forefront of observing and anticipating uncertainties related to those interactions (e.g., related to sustainability or safety). This implies that along with the strategy steering R&I "downstream", organizational structures and culture should support communicating "upstream" such uncertainties giving reasons to re-evaluate normative goals (Chapter 4). For instance, this can come by involving R&I representatives in strategy update rounds or in stakeholders hearings. In responsibility language, collaboration between strategy and R&I brings the normative (care) and procedural (responsive) approaches to responsibility into interaction. Furthermore, strategy management should include periodic evaluation of the "impact footprint" (the guiding question 2 in Fig. 5.1); whether impacts of the company's operations (accountability) are in line with the intentions announced in strategies, such as the care for environment or for future generations.

Implications at value chain level. The limited capacity to undertake accountability, and to be held accountable, in multi-actor bio-based value chains was the key finding in Chapter 3. This research, however, pointed to certain actors having authority to impose responsibility over and across entire value chains under formation: regulators, policymakers, and R&I funding bodies. The implications on those actors are considered below.

Regulators and policymakers have capacity to impose backward-looking responsibilities (liabilities) for broader societal impacts of innovation, such as related to environmental risk mitigation. These authorities support responsible innovation by coupling companies' license to operate with fulfilling certain societal preconditions (e.g., by environmental permits). The findings from the BC case (Chapter 3) brought out the need for interaction between legislators and R&I representatives. It can be recommended that the working culture of legislative bodies should enable this dialogue as part of their stakeholder involvement activities. Vice versa; from R&I representatives an active role is required in terms of providing insights and feedback on to what extent current or planned regulations encompass the risks and enable realization of the opportunities related to new inventions.

The public R&I funding bodies, at national and EU-level, also possess authority to impose backward-looking responsibility for implementing wider societal benefits. It was identified in Chapter 3 that the funding bodies establish accountability for broader societal impacts, by setting conditions for receiving funds, such as fulfilling carbon neutrality or employment increase targets. It is common that these instruments steer funding to R&I initiatives that involve consortia of several industrial and research members. For further accountability, it is recommended to monitor to what extent the actualized projects having received funding have eventually realized these impacts, and in what sense the individual consortium members have contributed to fulfilling those (i.e., distribution of accountability).

It needs to be underlined that while some actors were identified with capacity to impose responsibility across entire value chains, the systemic change towards a more comprehensive allocation of responsibilities in value chains remains far from being addressed. This thesis has provided insights into emergent industrial value chains from the viewpoint of R&I. That viewpoint alone cannot address how ethical aspects should be combined with commercial activity; how to assure that undesirable consequences of industrial activity do not become pushed into margins of value chains, passed over to next generations, or left to burden the most vulnerable segments of societies. However, meta-responsibility can provide a frame for further studies on the system level as well. The framework provides a systematized starting point to explore, for instance, how free market economy, intergovernmental organizations, or educational systems challenge (or support) the adoption of responsibility, how to instigate any change, and what that change should entail.

Finally, some implications can be drawn regarding the role research institutions collaborating with industrial parties in R&I. As was noted in earlier case studies, and further observed in Bio2X, there appears an agreement among R&I collaborators that the main responsibility for delivering the expected outcomes rests on the key investor (usually an industrial party). While this clarifies responsibilities (accountability) in backward-looking sense, it does leave space for joint undertakings of forward-looking responsibility for the outcomes (responsiveness). It suggests that those contracted for research should stand out when there appear reasons to re-examine goals, initial assumptions, or expected impacts. Likewise, investors should grant this space for research suppliers to contribute beyond completing the immediate tasks assigned to them. Based on the experiences at Bio2X, an observant mindset within research institutions is valued and also expected in industry.

Enabling activities can include, for instance, asking for feedback to initial plans, or joint brainstorming on interim research results.

5.4. Limitations and opportunities for further research

A few avenues for further research open up, when considering the limitations of what was possible to include into the scope of one doctoral thesis.

Regarding the theoretical backbone of this study, it should be noted that the referenced field of literature, that on RRI, is still relatively novel. Delving deeper into other fields of literature, such as philosophy or governance studies, can further enrich the understanding about responsibilities in R&I. The present approach was built on the basis of Pellizzoni's (2004) four elements of responsibility, but alternative conceptualizations of responsibility can be applicable as well, providing perhaps different insights into innovation management. Therefore, the meta-responsibility framework developed in this thesis rather demonstrates how *a* concept of responsibility can be used to support R&I activities.

When it comes to the field of application, innovation management, the main focus of this study has been on decision-making under uncertainty. There are multiple other elements in innovation management to which a meta-responsibility outlook could be applied – and through which the meta-responsibility approach can be developed further. For instance: applying responsibility framework on risk analysis and impact analysis in R&I projects, or on innovation process modeling, can be promising further application areas.

The main case studies considered in this thesis represent bio-based innovations: biorefining in Bio2X, bio-circular innovations in BC. Certain context-dependent issues are emphasized, such as asset-heavy production (implying less flexibility than in ICT, for instance), and complex value chains (multi-actor industrial ecosystems are required for valorization). Future case-studying in other industrial sectors could capture partly different discussions, tensions, and finally guiding questions (Fig. 5.1). It also needs to be noted that the number of case studies considered in this thesis was small. On the one hand, this is a matter of choice: having one primary case study (Bio2X) enabled an in-depth analysis of one case project. On the other hand, the number of relevant pre-existing case studies within RRI was for a long time very limited (Chapter 4, providing a review on those studies conducted in the private sector, was written in 2017).

Regarding methodology, the research conducted for this thesis has been "exploratory" in the sense that the research questions and the meta-responsibility framework were developed iteratively during the data analysis (as presented in Chapter 2). The protocol of semi-structured interviewing was particularly chosen to enable the exploratory approach. Yet, it should be acknowledged that the interview questionnaire and protocol would have been designed differently, had the framework been developed already at the stage of research design. That is: the validity and generalizability of the meta-responsibility map was not examined in a study particularly designed for that purpose.

There are, however, a few sources through which the broader applicability of meta-responsibility mapping can be appraised. First: for the supportive case study (BC, in Chapter 3), meta-responsibility provided complementary insights into challenges related to value chain formation, indicating that the approach is applicable also in other R&I projects. Second, in the context of Bio2X and BC the meta-responsibility framework appeared useful in categorization of pre-existing tools and methods for implementation of responsibility elements. Third, the interviewing itself triggered reflection on goals and responsibilities among Bio2X members, indicating that similar interventions could support decision making in R&I projects.

Fourth and finally, the setting of "employed ethicist" – the interviewer working in the case project – enabled observations on the development of Bio2X after data gathering and analysis. As explicated in Chapter 2, some of the issues remarked during interviews, at the early stages of Bio2X, became frequently discussed and also debated at later project stages several months after the interview period. In retrospect, the interviews had captured relevant discussions. This can be taken as an indication that collective reflection of responsibilities (with help of guiding questions, Fig. 5.1) could provide a frame for discussions throughout R&I projects.

How this setting of "employed ethicist" influences processes and outcomes of academic research is an interesting research question as such. At the end of each interview, the Bio2X respondents were asked to reflect on how being interviewed by a colleague may have influenced the atmosphere, their answers and behavior. It was generally considered positive that the project's substance was already familiar to the interviewer: there was less need to explain the background, which allowed more space for elaborate answers and self-reflection. Many respondents also remarked that it was easy to apply practical examples, knowing that the interviewer is well familiar with what information is confidential. Similar

interview was regarded unlikely in case of an external interviewer, owing to confidentiality as well as time constraints. On the other hand, for one interviewee the setting created a "top-down" sensation of taking for granted what the interviewer should know without saying. Not explaining (and asking) thoroughly, in case of assuming a shared knowledge basis, may create space for misinterpretation at data analysis. Finally, while a "relaxed atmosphere" of being interviewed by a colleague was greeted by some respondents, one respondent jokily mentioned about having kept a "small filter" as (s)he has to work with the interviewer also in the future. This reminds us that some matters can be easier brought out to outsiders. It would be an exciting avenue of further research to compare such findings with those from similar approaches such as "embedded ethicist" or "embedded humanist" (Flipse, et al., 2013; PRISMA-project, 2017).

References

Blok, V. & Lemmens, P. (2015). The emerging concept of responsible innovation. Three reasons why it is questionable and calls for a radical transformation of the concept of innovation. In B.J. Koops, I. Osterlaken, H. Romijn, T. Swierstra & J. van den Hoven (eds.), *Responsible Innovation 2: Concepts, Approaches, and Applications*, (pp. 19-35). Springer, Cham, Switzerland.

Blok, V., Tempels, T., Pietersma, E. & Jansen, L. 2017. Exploring Ethical Decision Making in Responsible Innovation: the case of innovations for healthy food. In L. Asveld, R. van Dam-Mieras, T. Swierstra, S. Lavrijssen, K. Linse & J. van den Hoven (eds.), *Responsible Innovation 3: A European Agenda?*, (pp. 231-249). Springer, Dordrecht, The Netherlands.

Ceicyte, J. & Petraite, M., 2018. Networked responsibility approach for responsible innovation: Perspective of the firm. *Sustainability,* 10(6), p. 1720.

Collingridge, D., 1980. *The Social Control of Technology*. London: Frances Pinter.

Dreyer, M. et al., 2017. Responsible innovation: A complementary view from industry with proposals for bridging different perspectives. *Sustainability,* 9(10).

Flipse, S.M.; van der Sanden, M.C.A.; Osseweijer, P., 2013 Midstream Modulation in Biotechnology Industry: Redefining What is 'Part of the Job' of Researchers in Industry. *Sci. Eng. Ethics*, 19, pp. 1141–1164

Owen, R. et al. (2013). A framework for responsible innovation. In R. Owen, J. Bessant & M. Heintz (eds.), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*, (pp. 27-50). John Wiley and Sons, Chichester, UK.

Pellizzoni, L., 2004. Responsibility and environmental governance. *Environmental politics*, 13(3), pp. 541-565.

Stahl, B. C., 2013. Responsible research and innovation: The role of privacy in an emerging framework. *Science and Public Policy,* 40(6), pp. 708-716.

Stilgoe, J., Owen, R. & MacNaghten, P., 2013. Developing a framework for responsible innovation. *Research Policy,* 42(9), pp. 1568-1580.

Stirling, A. (2008). "opening up" and "closing down": Power, participation, and pluralism in the social appraisal of technology. *Sci Technol Hum Values* 33(2): 262–294.

Timmermans, J., Yaghmaei, E., Stahl, B. C. & Brem, A., 2017. Research and innovation processes revisited : networked responsibility in industry. *Sustainability Accounting, Management and Policy Journal,* 8(3), pp. 307-334.

The PRISMA Responsible R&I Toolkit. Available online: http://www.rri-prisma.eu/rri-tool/embedded-ethicist (accessed on 11 June 2022).

Thompson, D. F., 1980. Moral responsibility and public officials: The problem of many hands. *Americal Political Science Review,* 74(4), pp. 905-916.

van de Poel, I. et al., 2012. The Problem of Many Hands: Climate Change as an Example. *Science and Engineering Ethics*, 18(1), pp. 49-67.

van de Poel, I. & Sand, M., 2018. Varieties of responsibility: two problems of responsible innovation. *Synthese*, pp. 1-19.

Von Schomberg, R. (2013). A vision of responsible research and innovation. In R. Owen, J. Bessant, M. Heintz. (eds.), *Responsible Innovation: Managing the responsible emergence of science and innovation and society*, (pp. 51-74). John Wiley and Sons, London, UK.

Appendices

Appendix A

This Appendix contains additional information regarding the Bio2X case study presented in Chapter 2 and Chapter 3.

The interview questionnaire used in Bio2X case study is first presented below.

Indicative interview questions

1. How would you briefly describe the project and its aims?
2. What is your role and area of responsibility in the project?
3. What inspires and motivates you in your work?
4. What kind of uncertainties does this kind of project face?
5. How are such uncertainties being addressed in the project?
6. What is corporate responsibility in your understanding?
7. In your opinion, how does the project link to corporate responsibility?
8. What kind of positive impacts do you foresee that the project could deliver in society and in the environment?
9. Is there something that concerns you regarding societal and environmental impacts of this project?
10. In matters of corporate responsibility, what kind of collaboration is needed between this project and the other units or functions the company?
11. At which stage is the project at the moment? (A description of R&I project stages is shown to interviewee, including exploration stage (applied research), development stage (pilot and demonstration), implementation stage (delivering value to consumers and society).)
12. In general, how is it to make decisions at this stage of the project?
13. Do you come up with a situation, where an expected positive societal or environmental impact has led to a decision affecting the project's direction?
14. Do you come up with a situation, where an expected negative societal or environmental impact has led to a decision affecting the project's direction?
15. Overall, how far do you think that a project like this should consider its wider societal impacts?
16. Thinking ahead, are there some issues related to wider societal impacts that will impact decision making at the coming steps of the project?
17. How have wider societal impacts been considered in (i) strategy and business model generation, (ii) at the team's internal discussions, and (iii) in relation to technical process development?

18. What stakeholders can you name for this project? (a definition of stakeholders as "those that can affect or be affected by the project' being shown to interviewee).
19. Of these, who do you consider as main stakeholders, i.e., who have the widest impact in the project?
20. How do you work with the main stakeholders? (For example, are they somehow involved in the decision making?)
21. Do you recall situations, where societal or environmental questions have been discussed with stakeholders?
22. How about the other stakeholders that you mentioned (at Question 18), how are those taken into consideration in the project?
23. Can you still think of some groups who you have not identified (at Question 18) but who could still be affected by the project's outcome in the future?
24. Ideally, what should happen to a product of this biorefinery, when launched to consumers?
25. Finally, is there something else that you would like to bring out?

The evolution of the research question, research hypotheses and research outputs during data analysis (MAXQDA coding rounds) in Chapter 2 is presented in Figure A1.1.

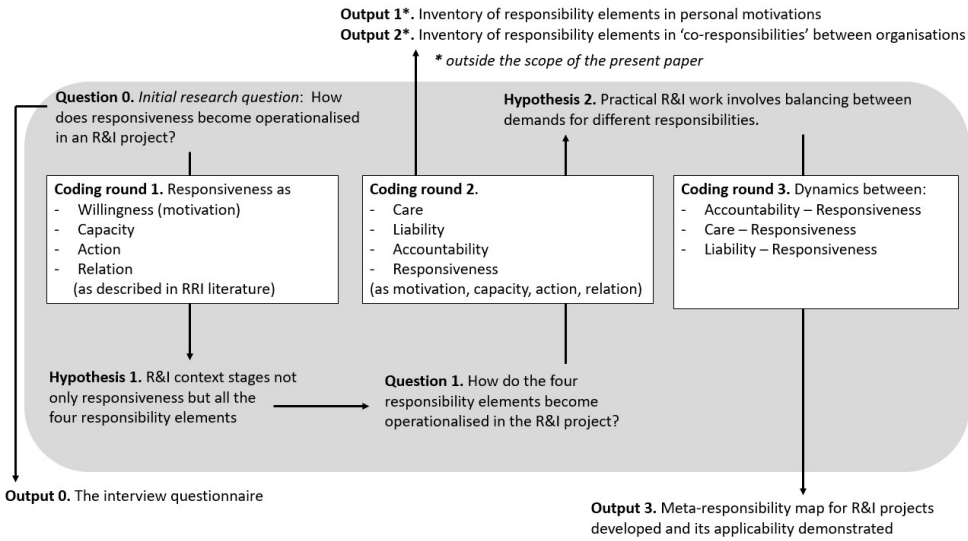

Figure A1.1. Evolution of the research question, research hypotheses and outputs during the analysis of Bio2X interview data.

Appendix B

The evolution of the research question, research hypotheses, research findings and outputs during data analysis in Chapter 3 is presented in Figure B1.1.

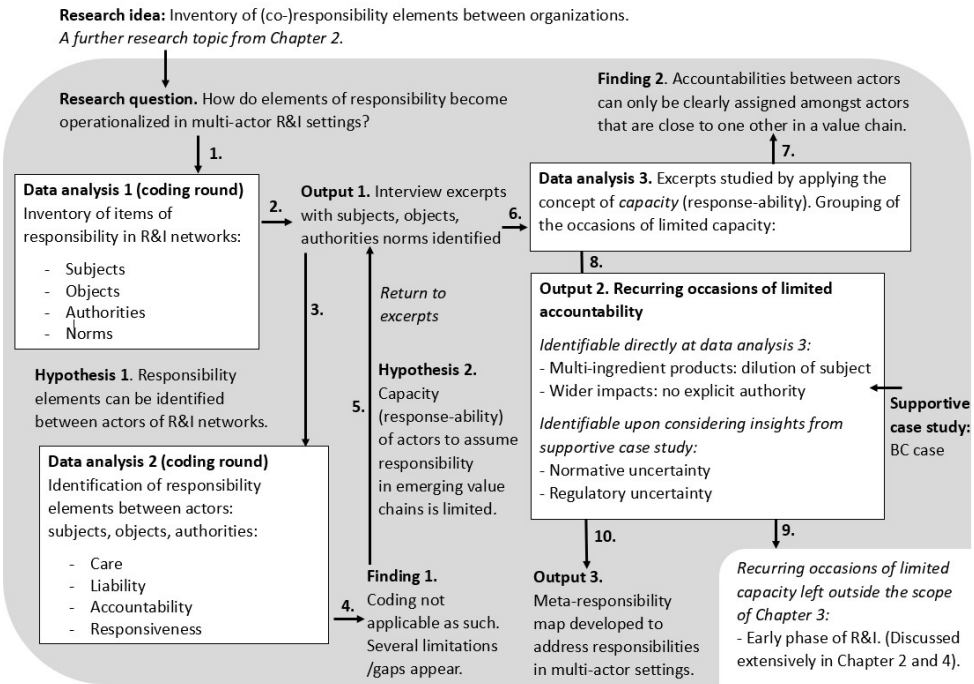

Figure B1.1 Evolution research hypotheses, findings and outputs during the analysis of Bio2X interview data.

The Output 1 in Fig B1.1, inventory of items of responsibility in Bio2X case, is provided in Table B1.1. This table lists the frequency of identified actors and topics being identifiable as an item of responsibility in Bio2 interview excerpts. For instance, “consumers” is identified five times as a subject (of responsibility), three times as an object (of which some instance is responsible), and as an authority (monitoring and sanctioning/ rewarding activities; in this case by purchase choice). Similarly, “resource efficiency” is identified once as an object (of the biorefinery developers to implement), and four times as a norm (prescribing conditions and criteria to decision making).

Table B1.1 Value chain items of responsibility (subjects, objects, authorities, norms) identifiable in Bio2X interview data.

Item of responsibility	Subject	Object	Authority	Norm
Auditing		1		
Bio-based				3
Biodegradability		1		5
Corporate executive board			8	
Carbon footprint		1		1
Communication		6		
Consumer brand owner	2		6	
Business case (for biorefinery)		13		
Company (Fortum)	29	1	3	
Corporate sustainability strategy			1	1
Consultant (market)	3			
Consumers	5	3	1	
Consumer/market demand			3	4
Corporate brand				2
Costs, cost efficiency		1		1
Demand, market / consumers			2	3
Durability (of product)				3
Employment (creation)				7
Product, end product		5		
Product, intermediate		3		
Environmental standards			7	3
Environmental impacts		6		3
Feedstock, acquisition		5		
Feedstock, availability		1		2
Feedstock, choosing		3		
Food security		1		1
IPR, freedom to operate		4		
Future business, profit		21		
Human rights				2
Industrial manufacturer	5		5	
Investment decision		2		
Investors (for biorefinery)			2	
Life cycle analysis (LCA)		4		
Life cycle, material/product		6		
License agreement			1	
Local communities (near biorefinery)	1	1	2	
Market assessment		2		
National economy	1	2	1	

Partnering (strategy)		3		
NGOs	4		1	
Piloting (biorefinery)		9		
Policymakers			4	
Product choice / validation		16		
Product quality		4		
Product safety				2
Price				1
Prototyping		2		
Public funder			1	
Purchase decision			2	
R&I Project/team (Bio2X)	76		11	
Recyclability				6
Recycling		1		
Regulators, safety			1	
Regulators, environment			1	
Renewability		2		
Research institute	4			
Resource efficiency		1		4
Resources, for R&I		1		11
Risk assessment		1		
Safety (of working)		1		3
Security of supply		1		
Self (own work role)	11		2	
Societal impacts		4		3
Society		1	2	
Shareowners			6	
Corporate (sustainability) strategy		1	4	1
Sustainability (general)		2		8
Corporate sustainability unit	1			
Technology choice / validation		13		
Technology developers	8		1	
Value chain (creation)		9		
Value chain, transparency		1		2
Vision		3	2	
Wellbeing, employees		2		1

Examples of analyzed data excerpts (Output 2 in Fig. B1.1) are given below (confidential information is anonymized).

- *Example of accountabilities amongst actors close to one another appear clear.*
  - "For us [*Bio2X, subject*], this [*piloting, object of Bio2X*] is about testing of fractionation technologies towards commercial scales [**accountability, for getting a proof of concept]**, and for the technology supplier [*subject*], it's about selling or licensing their technology [*object of supplier*] **[accountability, for sales]**. When it comes to making agreements with partners, it's always about bringing together different aims and wills".
- *Example of multiple aspects of responsibility co-existing.*
  - "Company's [*subject*] responsibility is about being profitable [*object*] [**accountability, for profit generation**], which also means that there is R&D [*object*] going on and put forth. That we develop new businesses and old businesses forth [**accountability, but also responsiveness for future profit opportunities**], so that they continue to be profitable also in future. Company's [*subject*] overall purpose is to make money [*object*], in the end. So when thinking of corporate responsibility, I immediately think the society's perspective. That's about bringing money [*object*] to the wheels of national economy *[authority]*. That's the responsibility [**accountability**] of all companies [*subject*]. There was a statistical presentation somewhere, about where the money to national economy is coming from. As comparison, there was the money demand of municipalities, cities and the State, and what needs to be the input from companies for covering that. That was eye-opening, very interesting statistics: It's companies that make the economy go around. Be it a majority state-owned company like us, or not. That's where the money comes from. It's up to the decision makers and politicians [*subject*] to decide where to use this money [**accountability, of politicians**]. It's for securing and protecting the society [**care, of interviewee for society**]."
- *Example of limited accountability (multi-ingredient products, dilution of subject).*
  - *Interviewee reflecting on where responsibility of one company reaches in value chain:* "Good question. [thinks]. It needs to stop somewhere, can't go forever. Let's think of textiles. If we [*Bio2X, subject*] deliver our material [*cellulosic fibers; object*] to someone [*downstream manufacturer, authority in the sense of evaluating fraction quality*], that link needs to be evaluated [**accountability**]. It's

impossible to examine further than that, the chains are very long [*subject unclear*]. We need to take the primary responsibility [**accountability**] for our fractions, and in some matters, the whole chain needs to be checked, I've understood companies do that sometimes. Somehow the responsibility should go along the chain. What an individual consumers does with their clothes, there we hardly can have an impact, but that the clothes would be made in ethical way [*ethical issue identified but subject not fully clear*]. The responsibility of understanding the choices one makes with this and that actor, it can be possible [***extending accountability of Bio2X by choosing with whom to partner***]."

- *Example of wider impacts of biorefining (no explicit authority)*
  - *Interviewee describing a situation where societal impacts had been considered at the project's decision making: "*I think the food chain security [*object*] we [*subject, Bio2X]* have already addressed. We don't compete with food production with straw, in fact, in case of straw we support food production if we transform from cotton to grain cultivation [for textile fibres]. What else to consider.. related to straw supply chain, whether it [straw utilization] is something that impoverishes soil, or are we somehow able to even improve soil condition? [*ethical issues identified, for some of those actions had been taken, despite that no explicit authority was identifiable*]"

List of Publications

- Sonck, M., Asveld, L., Landeweerd, L., Osseweijer, P. (2017). Creative tensions: mutual responsiveness adapted to private sector research and development. *Life Sciences, Society and Policy* 13 (1), 1-24.
- Sonck, M., Asveld, L., Osseweijer, P. (2020). Meta-responsibility in corporate research and innovation: A bioeconomic case study. *Sustainability* 12 (1), 38.
- Sonck, M., Asveld, L. (*Submitted*). A meta-responsibility outlook on evolving value chains of bio-based innovations.

Curriculum vitae

Matti Markus Sonck was born on 24th of June, 1981 in Salo, Finland. After completing his matriculation examination (high school diploma) at Halikko upper high school in 2000, he obtained a bachelor's degree in Social and Cultural Anthropology in 2004 from University of Helsinki. After an exchange student period in Universidade Federal do Rio de Janeiro, Brazil, he enrolled at Aalto University School of Chemical Engineering, in Espoo, Finland, obtaining a bachelor's degree on Science and Technology (Chemical Engineering) in 2010 and master's degree on Chemical Engineering (Applied Microbiology) in 2013. His Master's Thesis work, on cultivation of microalgae by utilizing power plant flue gases as carbon source, was commissioned by energy utility company Fortum. After graduation, Matti joined Fortum as a Research Expert, in Espoo, Finland, screening different biorefinery concepts for Fortum to develop business in the area of bioeconomy.

In 2015–2017, Matti took a study leave from Fortum to start his PhD. He joined the Biotechnology and Society group at Delft University of Technology as a PhD student, with Prof. Dr. P. Osseweijer as promotor. Since 2017 he has worked with his PhD alongside full-time working as Fortum's biorefinery program Bio2X: first as Research Expert, since 2019 as R&D Manager, and since May 2022 as Business Development Manager.

Acknowledgements

Every journey to PhD is for sure unlike the others. For me, it was a journey between two worlds, academic research and the daily work in R&I (and in between some occasions of personal life). Time thieves everywhere. Among them, I was the worst myself. I kept stealing time, from here and there, over the years, to complete this journey. There could have been worse options to use that time for.

There are also elements in every PhD that I imagine are shared. Doing PhD gives a great deal – that's what sacrifices are for. It often feels lonely. Even then, it's not solitaire. There are so many to thank for their support.

In TU Delft, I am grateful to you Patricia, as promotor during this PhD project, for allowing me to carry on with my research in this on-off-on setting. What I've learnt is that you will find a way to sort out whatever enables members of your group to thrive in their research. You bring alive what I call forward-looking in this book. Laurens, in my early PhD times you gave me glimpses to philosophy and its ways of thinking, a world that was new to me and what I've learnt to admire. Anka, you were there sorting things out, whatever those were, always with a good vibe, making everything seem so easy (and I can imagine that's not always the case). And Lotte, I'm so thankful to you for supporting me in figuring out the way forward from the trials-and-errors of early PhD (that's experimentation, right?). Somehow, you manage to supervise exactly at the right level of precision, questioning and giving advice but not giving it too detailed and pre-digested. Along with being a great supervisor, you were also an awesome colleague.

This journey started in 2015, when I took a two-year study leave from my daily work, and moved to the outrageously beautiful Delft. Mar and Maik, all that time you were my "neighbours" in the campus and in the town, respectively. The BTS group around those times – Mar, Philipp, Kasper, John, Zhizhen, Farahnaz, Zoë, Britte. Thank you for all the peer support in tricky situations, for lunch discussions and for the afters. That small ditch in the Botanical Garden doesn't count as canal dipping, right?

After those two years at TUDelft, I returned to Finland. While working at Fortum, I did my research fieldwork there as well. I am grateful to you Risto and Heli, as my

managers during those times, for allowing me to do interviews in the Bio2X team, and for your overall supportive spirit. Thank you my colleagues at Bio2X that participated in the interviews. As well as to those who joined the team later. You're truly a source of energy.

Doing PhD was not only a deep-dive into academic thinking, but also into the art of writing, scientifically, and in English. Again, Lotte thanks for your constant feedback. And John S., you were a really valuable support in proofreading English and advising in style. Ville, thank you so much for the last-minute help with the book cover and visuals.

To be truthful, this journey began long before the idea of doing a doctoral thesis was even born. Because of my family, of childhood and of today, this was possible in the first place. I've been lucky to have grown and to live surrounded by folks who've let me pursue my ideas, big and small. Thank you. I wish I have the patience and wisdom to allow that to you as well.

January 2023, Helsinki, Finland