CONNECT AND AFFECT

How stakeholder interactions facilitate technological change

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An introduction to technological innovations and stakeholder interactions

Present-day societies are facing *grand societal challenges*, such as dealing with climate change, depletion of natural resources, ageing populations, and more recently, the outbreak of a pandemic disease. These challenges transcend national borders and threaten people, communities, and the planet as a whole (George et al., 2016). Often, scientists and policymakers have pinned their hopes on technological innovations as (part of) the solution for addressing those challenges (e.g., Groen & Walsh, 2013; European Commission, 2011; Van den Hoven, 2014). However, the development and implementation of such solutions are not always successful. There are various aspects that may hinder success of technological innovations, because many different stakeholders need to be mobilised, who all have their own interests and stakes that affect their perceptions of the challenge at hand and the desirability of technological change (Köhler et al., 2019; Kuhlmann & Rip, 2014; Von Schomberg, 2014).

This dissertation focuses on how stakeholder interactions can contribute to the development and implementation of innovations, and thereby facilitate technological change. This will be done by applying concepts from different disciplines, including *science and technology studies (STS)*, *communication science*, and *science communication*. Despite various theoretical developments within these domains, until now, little attention has been paid to integrating them (Leeuwis & Aarts, 2011). STS scholars have provided a solid understanding of how technological innovations are being developed, which key components are needed for technological change, and how the desirability of this change can be assessed. In the field of communication science, emphasis has been placed on how different types of stakeholders interact with each other, although with little focus on the context of technological innovations. And in the field of science communication, much work has been done regarding the relationship between society, science and technology, creating a better understanding of how public engagement can influence this relationship. By combining the three disciplines, the aim of this dissertation is to provide a better understanding of the role of communication in the development and implementation of technological innovations and, more specifically, how stakeholder interactions can facilitate technological change.

In the remainder of this chapter, relevant concepts from STS, communication science and science communication are described, providing a theoretical foundation for this dissertation. First, to understand the paradigm of technological change as a social construct, section 1.1 addresses the so-called *socio-technical perspective* on technological change, including the prominent frameworks of *technological innovation system* (TIS) and *multi-level perspective* (MLP). Section 1.2 then elaborates on the creation of legitimacy and the development of socially robust innovations, which have been recognized as two key processes in facilitating technological change. Section 1.3 reflects on the concept of stakeholders and the role of communication in innovation processes. Section 1.4 addresses public engagement as an interactional process that might increase the legitimacy and robustness of technological innovations. After that the central research question and the two objectives of this dissertation are introduced (section 1.5). This chapter ends with an overview of the different studies that are presented in this dissertation (section 1.6).

1.1 Technological innovations as socio-technical systems

In innovation literature, technological innovations are often approached as *socio-technical systems*. Following this perspective, innovations are not seen as isolated technical artefacts but as entities that are in interplay with and embedded in other technical and non-technical entities in society (Borrás & Edler, 2014). These entities include technologies, markets, user practices, cultural meanings, infrastructures, policies, industry structures, and supply and distribution chains (Köhler et al., 2019). In this socio-technical system, a range of actors and social groups from academia, politics, industry, civil society, end-users, and the general public are involved, all of whom have their own resources, capabilities, beliefs, strategies and interests (Köhler et al., 2019). Taking into account these different social and technical elements, the development of technological innovations should not be regarded as a linear process based on research & development (R&D) capabilities (supply-push) or as a single process based on user needs (demand-pull) but rather as a dynamic, nonlinear process that occurs through the interactions of these different actors (Greenacre et al., 2012). To obtain an idea of how the socio-technical system approach can be applied in practice, an example of the electrical heat pump is given in Box 1.1.

Various analytical frameworks have been developed based on this perspective, to enhance the understanding of the patterns and dynamics of technological innovations. The most important and influential frameworks are the *technological innovation system perspective* (TIS) and *multilevel perspective* (MLP) (Köhler et al., 2019; Markard & Truffer, 2008a; Walrave & Raven, 2015). These frameworks have been used to study technological change on different levels. The TIS framework is often used to analyse the prospects and dynamics of a particular innovation, e.g., the electrical heat pump, which is referred to as an 'emerging technology perspective' (Markard & Truffer, 2008a). By studying a single innovation, factors that may hinder or promote its development can be identified (Wieczorek & Hekkert, 2012) and insights can be gained regarding the potential of this innovation to contribute to society. The MLP framework is often used to study technological change on a more aggregated level and focuses on the investigation of broader transitional processes in society, e.g., the transition towards sustainable heat, involving a variety of innovations (Markard & Truffer, 2008a).

1.1.1 The technological innovation system (TIS) framework

The TIS framework is an analytical construct that approaches innovations as a "network of agents interacting in a specific industrial area under a particular institutional infrastructure" (Carlsson et al., 2002, p. 237). Within the TIS framework, the technology is the starting point, which includes both tangible artefacts and knowledge (Hekkert et al., 2007), and the framework aims at creating an understanding of how the socio-technical system around a particular technology functions.

Box 1.1 *Electrical heat pumps*

The Dutch government has started down the path towards sustainable heat to drastically reduce the country's CO2-emissions; they have decided to disconnect the country's natural gas by 2050. This decision was motived by the Paris Agreement, in which countries committed to come up with measures to mitigate global warming, and by the seismic activities in the province of Groningen in the northern part of the Netherlands. The discovery of the gas field in Groningen in 1959 has led to a large national dependency on natural gas, with more than 8 million households (90%) connected to the gas grid. Disconnecting every household from the gas grid is a major technical and social challenge, as it requires citizens to adopt alternative heating systems.

The electrical heat pump is one of the alternatives that can be implemented in the residential sector. Those pumps are based on and connected to various technical artefacts. However, they will only be a sustainable solution if they are fed with renewable energy; therefore, an increase in renewable energy sources is needed to meet the (potential) demand. Furthermore, electrical heat pumps can only heat effectively if houses are well-insulated, and many of the houses in the Netherlands need improvements in this regard. Additionally, a widespread implementation of electrical heat pumps will increase the demand of the electricity grid, which might exceed its capacity; thus, the infrastructure of the electricity grid needs to be expanded or adjusted.

A broad range of stakeholders is involved in the development and implementation of electrical heat pumps, including engineering firms designing the systems, manufacturers of heat pumps (producers of evaporators and compressors), installers of the heat pumps, contractors workers who insulate houses, and users (homeowners and housing corporations). Other stakeholders include universities involved in improving the effectiveness of heat pumps; (local, regional and national) governmental bodies involved in providing a regulatory framework (e.g., a heat transition strategy and subsidies); companies involved in the generation and distribution of renewable energy, and the net distributors.

Interactions between these stakeholders takes place within an institutional framework that is crucial for the successful development and implementation of heat pumps. To disconnect eight million houses from the gas grid, the Dutch national government has requested every local government to write a heat transition strategy, outlining the transition towards sustainable heat for all neighbourhoods. These strategies have a lot of influence on the potential demand of electrical heat pumps. Furthermore, the Dutch government has issued subsidies for homeowners to insulate their houses. However, despite these subsidies, the costs for implementing a heat pump in a badly insulated house is still relatively high, and homeowners doubt whether they will see return on investment. Governmental bodies struggle with how to create acceptance for technologies such as the electrical heat pump. Technological start-ups might be working on the development of better and cheaper pumps, but need advanced technical knowledge for that and financial resources to be able to develop them on a large scale, as well as the interest of (potential) users to survive in a competitive environment. The broad range of stakeholders involved in the transition towards sustainable heat all have an influence on the development and implementation of electrical heat pumps. Interactions between them, in terms of communication strategies, sense-making, framing, and public engagement, all play an important role in the success of this development and implementation

As such, the TIS framework contributes to understanding the complex nature of the emergence and growth of new technologies (Bergek et al., 2015, p. 52). In the framework, three types of components are used to define an innovation system:

1. *Actors* include a variety of academic, societal, economic, and governmental entities positioned along the value chain who are either directly or indirectly involved in the innovation process.
2. *Networks* consist of the dynamic relationships between actors. They can be formal or informal and orchestrated or non-orchestrated, and they can evolve around technological tasks or have a political agenda (Bergek, Jacobsson, Carlsson et al., 2008). In addition to networks of actors, Bergek, Jacobsson, and Sandén (2008) argued that technological artefacts can also be linked together and form their own networks.
3. The *institutional* component of the TIS framework regulates the interactions between the actors. Those institutions may come as hard regulations controlled by judicial systems and as norms and cognitive rules controlled by social systems (Bergek, Jacobsson, &, Sandén, 2008).

Applying the three components of the TIS framework to the electrical heat pump scenario mentioned in Box 1.1, a broad range of *actors* can be identified who have a make-or-break influence on its development and implementation. These actors include researchers, firms, national, regional and local governmental authorities, energy companies, housing corporations, net distributors, installation firms, and (potential) end-users. *Networks* between those actors are orchestrated both at the national level with the establishment of so-called climate tables, where different types of actors are invited to contribute to a national climate agreement, and at the local and regional level with the drafting of regional energy transition visions and regional energy strategies. These types of networks indirectly influence the development of electrical heat pumps; but there are also networks that are directly connected to them, such as the Dutch Heat Pump Association, which is a network of producers and importers of heat pumps. The *institutional component* is especially important for the development and implementation of electrical heat pumps. Because of the policy issued by the Dutch Minister of Economic Affairs and Climate that the Netherlands will be natural gas free by 2050, households need to find an alternative source for heating their houses, which has created an ideal situation—i.e., a great potential market—for the implementation of the electrical heat pump. However, there are various factors that might hinder the implementation of electrical heat pumps. For instance, the current electrical heat pumps are relatively expensive and can only be implemented in well-insulated houses. To compete with other heating alternatives, it might be necessary to develop more efficient and effective heat pumps. Furthermore, although the energy policy has been issued, it does not mean that every Dutch citizen accepts the policy or will actually adopt such heat pumps, as this depends on the norms and expectations of end-users and the general public.

In the literature on TIS, it is assumed that the components of a system—i.e., the actors, networks, and institutions—shape the development and implementation of an innovation. However, by only focusing on these components, little can be said about their influence on the innovation process and the technological change (Bergek, Jacobsson, Carlsson et al., 2008). Therefore, the *functional approach* of the TIS framework has been introduced, which systematically maps the activities that take place in the innovation system and that are needed for the successful development, diffusion, and use of new technologies (Hekkert et al., 2007; Bergek, Jacobsson, Carlsson et al., 2008). Hekkert et al. (2007) and Bergek, Jacobsson, Carlsson et al. (2008) distinguished various core functions of the activities in the TIS framework: *knowledge development and diffusion, influence of direction of search, entrepreneurial experimentation, market formation, resource mobilisation, legitimation*, and *development of externalities*.

Knowledge development refers to the development of new knowledge and insights in research groups at universities and at R&D-departments, and knowledge diffusion involves the sharing of knowledge with other actors. Influence of direction of search includes the incentives and/or pressures for organizations to engage in the innovation system based on visions, expectations, and beliefs in growth potential and relevance of the product/technology. Entrepreneurial experimentation encompasses the activities needed for developing the knowledge into commercialised products. Market formation is the development of a market around a product/technology, which is based on consumers who are interested in the product. For emerging technologies a market may not yet exist. Resource mobilization involves the attraction of financial (such as subsidies or investments) and human resources (skilled employees) needed for the development and implementation of the innovation. Legitimation refers to the creation of social acceptance of the innovation and alignment with relevant institutions; an innovation needs to be considered feasible and desirable by relevant actors in order to mobilise resources and to create a market. The development of externalities refers to both external development in society that can possibly influence the technology, such as crises, structural political developments, and demographic developments, and the development of other, complementary, technologies, which are not part of the TIS, but may have influence on them (Berget, Jacobsson, Carlsson et al., 2008). For instance, in the context of sustainable heat, besides electrical heat pumps other heating systems can be used as an alternative for natural gas as well, for instance district heating. The development and implementation of this innovation influences the system of electrical heat pumps.

The TIS framework and the functional approach have been mainly applied to identify system weaknesses and to inform policymakers about the potential for technological change (Markard & Truffer, 2008b; Plank et al., 2016). This dissertation extends the TIS framework as an analytical approach, by studying the stakeholder interactions and addressing different

stakeholder perspectives. These interactions and perspectives provide a better understanding how stakeholders can influence the development and implementation of technological innovations.

1.1.2 The multi-level perspective (MLP) framework

The MLP framework is based on an evolutionary perspective on innovations, and provides an understanding of how technological change evolves in society. Not every technological innovation has the same impact or requires the same changes in society. The MLP framework distinguishes between incremental and radical innovations; the former refers to improvements to existing technologies or innovations within a technological system, and the latter refers to innovations that transform entire production and consumption systems (Geels et al., 2018; Köhler et al., 2019). The MLP framework explains how technological change is influenced by the dynamics on three analytical levels in society (Geels, 2002). These levels are:

1. The socio-technical landscape, which forms an exogenous environment beyond the direct influence of actors involved in technological innovations;
2. Socio-technical regimes, which represent the institutional structuring of existing systems leading to path dependence and incremental change; and
3. Niches, which are protected spaces and the locus for radical innovations.

The socio-technical landscape refers to the structural trends in society, such as cultural preferences, demographics, and macropolitical developments (Geels et al., 2018). The landscape is not part of the socio-technical system, but the external environment that influences the system. Therefore, it cannot be directly influenced by actors who are involved in the development and implementation of innovations. Changes in the landscape do occur, but they often take decades, such as climate change and globalization, or are brought about by external shocks, such as a war or a pandemic (Geels & Schot, 2007).

The socio-technical regime refers to the incumbent socio-technical system, which includes technologies, industries, supply chains, consumption patterns, policies, and infrastructures that are dominant in society. These system elements are shaped by various actors, whose perceptions and actions are shaped by formal regulations and informal institutions, such as shared meanings, heuristics, routines, and social norms (Geels & Schot, 2007). An example of a socio-technical regime is the gas-based heating system in the Netherlands; the strong dependency on natural gas, which has led to a lock-in of the Dutch residential sector (Miedema et al., 2018). Various incremental technologies have been implemented to make the heating of houses more efficient, such as home insulation or high-efficiency gas boilers. However, the dependence on natural gas has always remained; as described in Box 1.1, it takes much more effort to implement an innovation for heating that is based on a resource other than natural gas. Such types of innovations are labelled in the MLP framework as niche innovations.

Niche innovations can also be labelled radical innovations, as they refer to new technologies that deviate on one or more dimensions from the socio-technical regime. Niche innovations coexist with existing technologies and typically require long-term and highly risky innovation programmes (Smith, 2008). To be successfully implemented in society, these innovations must overcome a wide range of uncertainties, including techno-economic, financial, cognitive, and social uncertainties (Geels et al., 2018). To compete with existing technologies that do not have these uncertainties, niche innovations often depend on integrated public and private actions, such as investments and subsidies, which create protected spaces for their development (i.e., niches) (Smith, 2008). Niches allow stakeholders associated with these innovations to address and reduce the uncertainties (Geels, 2002). Niche innovations develop over time through interactions between learning processes, social networks, visions, and expectations (Kemp et al., 1998). The electrical heat pump (c.f., Box 1.1) is an example of a current niche innovation in the Netherlands, because its implementation in most Dutch houses, which are connected to the gas grid, requires drastic changes in the current heating system, including the insulation of houses, a different heating infrastructure, changes in the electricity net, and new types of knowledge about the heating system among Dutch households. Actors in favour of electrical heat pumps can actively shape these aspects through their interactions with other stakeholders. However, actors who have a stake in the socio-technical regime may try to hinder the development of a niche innovation.

The MLP framework focuses strongly on the agency of power, specifically on power struggles between incumbent regimes and upcoming niches (Markard & Truffer, 2008a). This focus guides the attention towards the institutional framework in which technological innovations are being developed. However, scholars have criticised the MLP framework for its lack of attention to interactional processes and an insufficient conceptualization of roles and strategies at the actor level (Geels & Schot, 2007; Markard & Truffer, 2008a; Smink, 2015). This dissertation aims to enhance the understanding of the actor level of the MLP framework by focusing on stakeholder interactions needed for facilitating technological change.

1.2 Technology legitimacy and socially robust innovations

Due to the scope and complexity of most grand societal challenges, solutions of these challenges may be (partly) based on radical innovations (Geels et al., 2018; Walrave & Raven, 2014). Radical innovations often comprise new knowledge and complex innovation processes since they typically depend on the co-development of new market structures, new actors, and new social norms and regulations (Markard & Truffer, 2008a). These type of innovations might significantly influence society at large or specific communities and therefore require collective action among different actors along the value chain (Bergek, Jacobsson, Carlsson et al., 2008; Geels & Schot, 2007). However, these innovations struggle with the so-called liability of newness (Binz et al., 2016). This liability implies that radical innovations are often in conflict with established norms and regulations, and that actors experience unfamiliarity with the working principles of the innovation and uncertainty regarding its (potential) effects and return on investment. Consequently, proponents of a radical innovation have to spend

considerable efforts in creating legitimacy for the innovation to get other stakeholders on board (Binz et al., 2016).

Legitimacy has been recognised in both the TIS framework and the MLP framework as an important precondition for the development and implementation of technological innovations. An often used definition of legitimacy is “a generalised perception or assumption that the actions of an entity are desirable, proper and appropriate within some socially constructed system of norms, values, beliefs, and definitions” (Suchman, 1995, p. 574). In the context of technological change, this entity is the technological innovation. Geels and Verhees (2011) distinguished between regulatory and cultural legitimacy; the former involves whether the technology matches (governmental) regulations and the latter involves whether the technology is accepted by the wider public. Later, Binz et al (2016) introduced a framework of technology legitimacy based on four pillars: the cognitive, normative, regulative and pragmatic pillar. The cognitive pillar refers to knowledge and understanding of the technology; the normative pillar to whether the technology is in accordance with societal norms and values; the regulative pillar to whether the technology is in line with regulations; and the pragmatic pillar to the (perceived) utility of the technology for particular stakeholders or society at large. Technology legitimacy must be created by various actors involved (directly and indirectly) in the development, implementation and utilisation of technological innovations; it is often not an effort of a single actor but a collective action of multiple organizations (Binz et al., 2016). Interactions that have been studied to increase legitimacy, include advocacy, lobbying, networking, and framing (e.g., Binz et al., 2016; Geels & Verhees, 2011; Smink, 2015; Tosun & Schaub, 2017). Nevertheless, both Binz et al. (2016) and Geels and Verhees (2011) emphasised that there is still much to learn about how early actors in a new technological field can create, sustain and enhance legitimacy of innovations. Therefore, this dissertation aims to provide a better understanding of how stakeholder interactions can enhance legitimacy, and thereby facilitate technological change. This will be done by studying the dimensions of legitimacy, the factors that influence stakeholders’ perceptions of innovations, and the aspects of technological innovations that matter in this regard.

Besides spending efforts on creating a positive perception of technological innovations, legitimacy can also be enhanced by taking into account societal norms and values in the development of technological innovations. This has not only been emphasised as a way to creating legitimacy, but also to create *socially robust innovations*. It has been argued that technological innovations that are being developed as (part of) a solution for societal challenges are inherently good (Von Schomberg, 2014). But, technological innovations may still have negative impacts on society as well, thereby creating new challenges. Besides, perspectives on what the pressing societal problems are and what constitutes as their solutions differ across various societal groups (Kuhlmann & Rip, 2014). It is therefore important to reflect on (potential) societal impacts of technological innovations and take into account the needs of different stakeholders in the (early) developmental phase, which might lead to socially robust innovations (Cuijpers et al., 2014; Gudowsky & Peissl, 2016; Von Schomberg, 2014).

Take for instance the development of nanotechnology (cf., Box 1.2). Nanotechnology enables novel applications many areas, such as healthcare. One type of application is sensor technology for diagnostic devices that can detect diseases at a very early stage (years before symptoms are visible). While such a diagnostic device can provide promising solutions for curing or preventing particular diseases and thereby decrease the burden on the healthcare system, it can also lead to negative consequences. For instance, not everyone wants to know at an early stage if they have a high risk of developing a disease in the future, especially if there is not yet a cure for it. And the information obtained with the diagnostic device might be misused by other parties, such as health insurance companies or employers, which may negatively affect the life of individuals.

The importance of (early) consideration of societal needs and values in the development of technological innovations is increasingly recognised by researchers and policymakers. Although responsibility in innovation practice is not a new idea, the notion to steer the development of innovations towards societal beneficial objectives was introduced in the 21st century and has been labelled using the term *responsible research and innovation* (RRI) (Rip 2014). The concept of RRI has been addressed frequently in the literature (e.g., De Saille, 2015; Schuijf & Dijkstra, 2020; Stilgoe et al., 2013; Von Schomberg, 2012). The most often cited definition of RRI, which was also adopted by the European Commission, is Von Schomberg's definition. He defines RRI as "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 desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific technological advances in our society)" (Von Schomberg, 2012, p. 9). In this definition, both the *product* and *process* dimension of innovations are acknowledged. Based on a democratic innovation process, new insights can be gained that can lead to more socially robust innovations, but the democratic nature of the process itself can already make innovations more legitimate. Taking into account these two dimensions in RRI, there is general agreement among scholars, that responsible forms of innovation should be aligned to social needs and include relevant actors in two-way consultation (De Saille, 2015). However, RRI is still a concept in development, and much remains unclear of how to put it into practice (Schuijff & Dijkstra, 2020). This dissertation addresses how to bring RRI in practice by studying how stakeholder interactions can lead to more socially robust innovations, which can increase legitimacy as well.

1.3 Stakeholders and interactions

The TIS framework, the MLP framework, and the RRI perspective all recognise the importance of interactions between various actors for the development, implementation and utilisation of technological innovations. In communication science, these actors are often been labelled as *stakeholders*, thereby emphasizing their stakes—in terms of interest and perceptions—in the process and the outcome. The concept of stakeholder has been derived from management literature, in which Freeman's influential work on stakeholder theory has

laid a foundation. Freeman (1984) defined a stakeholder as "any group or individual who can affect or is affected by the achievement of the organization's objectives" (p. 46). In the context of technological change, the narrow focus on a particular organization can be replaced by the broader perspective on 'innovation'.

Based on Freeman's definition, various specific stakeholder approaches have been developed for identifying relevant stakeholders to interact with, which can be divided in instrumental and normative approaches (Mitchell et al., 1997; Reed et al., 2009). The instrumental approach emphasises a pragmatic definition of stakeholders, and regards a stakeholder as a group or individual without whose support the innovation would be threatened (Reed et al., 2009). The normative approach emphasises the legitimacy of stakeholder involvement and the empowerment of actors in the development of technological innovations, defining a stakeholder as a group or individual that is or might be affected by the innovation (Reed et al., 2009). These stakeholder approaches help to identify relevant actors in innovation processes, but as such provide little insights in the interactions that are needed for facilitating technological change.

Communication science scholars have studied the interactions and dynamics between people for decades. Communication can be defined as "the process by which people interactively create, sustain, and manage meaning" (Conrad & Poole, 1998, p. 15). Various communication processes that can be related to this definition have been explored and studied, such as message framing, sense-making, forming and influencing perceptions, engagement, networking, and managing (public) relations. These processes have been studied in different contexts, including the cognitive, interpersonal, intercultural, persuasive, corporate and organizational, mediated, mass communication, and technical context (Dainton & Zelley, 2019), which led to several subdisciplines of communication science. Although the latter context seems to be most strongly related to this dissertation, the emphasis in technical communication is predominantly on the usability and user experience of technological innovations. This may be relevant for the communication between developers and end-users, but as the socio-technical perspective shows, there is a great variety of stakeholders included in the development of implementation of innovations, who shape and affect technological innovations throughout the whole innovation process.

Box 1.2 *Nanotechnology for diagnostic devices*

Nanotechnology is the study, design, creation, manipulation and use of materials, devices or systems at an extremely small scale, i.e., approximately 1-100 nanometres. To give a better understanding of this scale, the diameter of a human hair is approximately 80,000-100,000 nanometres. When fabricating on such a small scale, new materials can be created, and existing materials can be improved by altering their properties. This has led to high expectations about nanotechnology as an enabling technology for innovations in areas as diverse as energy, healthcare, electronics, food and construction. Although many products already contain nanoparticles (e.g., invisible sunscreens with nanosized versions of zinc oxide and titanium oxide to block out sunlight) applications that might have a great effect on society are still in development.

Promising applications in the health context, for instance, are (early) diagnostic devices. Researchers are developing sensors based on nanotechnology that can measure biomarkers in bodily substances, such as urine or blood. These biomarkers are measurable indicators of a particular disease and also give an indication of its severity and the stage. They are promising as they have potential to reliably detect diseases, at an earlier stage and may be faster or cheaper. Examples of diagnostic devices that are being developed by companies and researchers include devices for detecting type 2 diabetes at an early stage (ten years before the symptoms), for detecting bladder cancer in urine, and for detecting Alzheimer's disease at an early stage. Better, earlier, and cheaper detection of diseases improves the possibilities for treating them effectively or preventing them. For instance, in the case of type 2 diabetes, it is helpful for high-risk people to adapt their lifestyle at an early stage to prevent or postpone negative symptoms of the disease.

However, there are various challenges related to developing these devices. On the technical side, these challenges include the development of sensors that are sensitive enough to 'catch' the biomarker and to connect the right information to it and the development of devices that can be produced on a large-scale and that can be used by healthcare professionals or even by (potential) patients themselves at home. On the social side, questions arise regarding the type of diseases to detect at an early stage. For instance, do people want to know if they are at a high risk of getting Alzheimer's disease, for which there is not yet a cure? Furthermore, there are many practical questions related to the implementation of an early diagnostic device. Who will pay for the use of the device? Most healthcare systems are based on curing diseases and focus on detection based on symptoms, not on preventing disease. In addition, who should be able to obtain an early diagnosis? If every Dutch citizen were allowed to get an early diagnosis for various diseases, it will put a heavy financial burden on the healthcare system. Another question involves the use of the diagnostic device; i.e., should people be able to operate these devices by themselves at home, as is the case with pregnancy tests, or should the devices be operated only by healthcare professionals? All of these questions should already be considered in the developmental stage of such devices to align them with societal needs and values and, as such, enhance their (social) desirability.

Leeuwis and Aarts (2011; 2016) are among the few scholars who have combined innovation studies with communication science. They proposed a rethinking of communication in innovation processes based on what they call a *construction model*, instead of the often applied *objective* and *subjective models* of communication. The objective model focuses on the exchange of information from sender to receiver, in which the communication processes are initiated by the sender and the aim is the creation of acceptance for technological change. The subjective model also emphasises the exchange of information between sender and receiver, but recognizes that both might have a different perception or interpretations of the information. This model acknowledges the importance of processes of sense-making and framing. The construction model does not distinguish between sender and receiver, but instead emphasises that the outcomes of communication processes are based on the construction of meaning through interactions between actors (Leeuwis & Aarts, 2011). The authors have adopted the construction model based on the idea of the nonlinear development of innovations, as recognised by the socio-technical system perspective (Leeuwis & Aarts, 2016). Instead of innovations being developed by scientists, disseminated through intermediaries, and then put in practice by users, it is assumed that they are usually based on an integration of ideas and insights from a diverse group of stakeholders. There is not one stakeholder who conducts and controls the innovation process, but all involved stakeholders have their own perspectives and interests in the innovation and together they influence technological change.

Based on the construction model, Leeuwis and Aarts (2011) emphasised the importance of everyday conversations and informal interactions between stakeholders in the development and implementation of innovations. They argued that communication professionals in innovation processes may look at their role as intermediaries who shape a context in which a positive meaning of an innovation can be created through networking, social learning and power dynamics rather than the "communicative engineering and planning of predefined changes" (p. 32). Although this dissertation recognises the importance of creating and sustaining meaning of innovations through interactions, it also assumes that it is not only informal interactions between stakeholders that shape the innovation process. Instead, the development and implementation of innovations can be influenced and orchestrated by various stakeholders. By recognizing both the importance of the creation of meaning through interactions and the potential of stakeholders influencing the innovation process, this dissertation explores various types of interactions that can affect the development and implementation of technological innovations.

1.4 Public engagement as a key interactional process

Public engagement is a key interactional processes that has been studied in the context of technological change and RRI. It is regarded as a process that can increase legitimacy of the development of science and technology and add value to the innovation (Jarmai & Vogel-Pöschl, 2020; Jasanoff, 2014; Reed et al., 2018). The concept of (public) engagement has received considerable attention in the field of science communication, in which much research has been done on how to engage publics in the development and implementation of technological innovations. The discussion about the role of public engagement in technological change can be traced back to the 1960s, when scientists and policymakers became increasingly aware that publics no longer unconditionally accepted science and technology. The first critical counterarguments were raised against scientific developments and the publics became aware of the adverse effects of technological change (Bauer et al., 2007).

Within science communication the notion of public engagement evolved from informing the public to having a dialogue with the public. Initially, science communication was based on the deficit model, assuming that a lack of knowledge and misrepresentation of science and technology by the mass-media caused negative attitude towards technological change. The general idea was that a better understanding of science and technology would lead to more favourable attitudes (Bucchi & Neresini, 2008). However, various studies (e.g., Davies, 2008; Sturgis & Allum, 2004; Wilsdon & Willis, 2004) showed that informing or persuading the public did not suffice, as the relation between knowledge and attitude is not a straightforward one. In the context of GM food, for instance, citizens who became more knowledgeable also became more critical (Wilsdon & Willis, 2004). In the 1990s, the 'deficit model' has been replaced by the 'dialogue model'. This model emphasises the importance of two-way communication between science and society, assuming that a dialogue on equal footing can restore trust in science and technology and enhances legitimacy of its governance (Hennen & Pfersdorf, 2014).

Although the value of a dialogue between science and society has been recognised, the debate on genetically modified organisms (GMOs) in Europe uncovered a deep crisis of public trust in the new technology and its governance. Consequently, the view of restoring publics' trust in science and technology through engagement started to change (Russel, 2013). Instead of technocratic development of technological innovations far away from the publics and adding a top-down dialogue process for increasing trust in these innovations, the emphasis was put on developing innovations based on societal needs and values through upstream engagement. This type of engagement addresses the creation of legitimacy of technological innovations through enhancing trust by opening up the innovation process and by creating socially robust innovations. This notion of engagement has also been adopted by scholars and policymakers addressing RRI. They have increasingly realised that in order to create sustainable and desirable technological change, they should include publics' needs and concerns on their agenda and empower the publics to actively shape this agenda (Owen et al., 2012). Furthermore, scientists and policymakers have recognized the potential of engaging with various stakeholders in the development and implementation of innovations, as they may bring in different types of knowledges and make relevant contributions to the innovations (De Saille, 2015; Polk, 2005).

1.5 Research question and objectives

This dissertation reflects upon the role of communication in innovation processes by integrating concepts of the discipline of STS, communication science, and science communication. In this dissertation communication is approached as the interactional processes through which stakeholders create, sustain and manage meaning of the technological innovation. The central research question is:

How can stakeholders influence the development and implementation of technological innovations, and thereby contribute to technological change?

This dissertation includes several radical innovations that might be part of the solution of a societal challenge, and as such may have considerable impact on society. Key concepts from the three disciplines (STS, communication science, and science communication) are used as a starting point, which has led to two objectives of this dissertation.

First, based on the STS literature, this dissertation approaches technological innovations as a socio-technical system. This socio-technical system perspective has led to relevant analytical frameworks that can be used to study the stakeholder dynamics in innovation processes, including the TIS framework and the MLP framework. The TIS framework provides insights in the complexity of the innovation process and the various functions that must be addressed for the successful development, implementation, and diffusion of technological innovations. The MLP framework has created a better understanding of technological change by distinguishing three analytical levels in society, explaining the efforts that must be taken to develop and implement a radical innovation against its competing, existing, technologies. However, as various scholars have pointed out, the stakeholder interactions needed to address the functions and to affect technological change have remained understudied (Borrás & Edler, 2014; Geels & Schot, 2007; Köhler et al., 2019; Markard & Truffer, 2008b; Smink, 2015). This lack of knowledge leads to the first objective of this dissertation.

The first objective of this dissertation is to create an overview of the stakeholder interactions that influence the development and implementation of technological innovations.

Second, this dissertation specifically focuses on legitimacy and socially robustness as key outcomes of the stakeholder interactions in innovation processes. Legitimacy implies that a technological innovation is being perceived by various stakeholder groups as desirable and appropriate, and is aligned with societal norms, values and regulations. The creation of legitimacy has been emphasised in both the TIS-framework and MLP-framework as an important precondition for the development, implementation and use of innovations. This is especially the case for radical innovations, as they often comprise new knowledge, new actors, and new norms and regulations. Therefore, these type of innovations often struggle with a liability of newness, which implies that stakeholders in favour of the innovation must spend considerable efforts in changing the norms and regulations and influencing the knowledge about and perception of the innovation among other stakeholders (Binz et al., 2016). Various interactions for creating legitimacy of technological innovations have been studied, such as framing (Geels & Verhees, 2011), lobbying and advocacy (Binz et al., 2016; Tosun & Schaub, 2017), and public engagement (Kyllönen, 2012; Stilgoe et al., 2014). However, there is still much to learn about how proponents of an innovation create legitimacy for innovations (Binz et al., 2016), how legitimacy can be gained through collective sense-making of technological innovations (Geels & Verhees, 2011), and how new approaches to public and stakeholder engagement contribute to legitimacy (Leeuwis & Aarts, 2016).

Furthermore, this dissertation addresses how stakeholder interactions can lead to more socially robust innovations. Public and stakeholder engagement have not only been recognized as processes that can enhance legitimacy by opening up the innovation process, but also by bringing in different types of knowledge and the articulation of norms and values, which can lead to socially robust innovations (Groves, 2011). The notion of steering the innovation (process) towards societal beneficial objectives has been addressed by the concept of responsible research and innovation (RRI). RRI emphasises how the acceptability, sustainability, and desirability of an innovation can be enhanced through two-way interaction between stakeholders (De Saille, 2015; Von Schomberg, 2014). Although, scholars have recognized the importance of RRI, it is still a concept in development and much remains unclear about how to operationalise it and how it can stimulate the development of socially robust innovations (Leeuwis & Aarts, 2016; Schuijff & Dijkstra, 2020).

The second objective of this dissertation is to gain a better understanding of how stakeholder interactions can support the creation of legitimacy of technological innovations and contribute to socially robust innovations.

1.6 Dissertation outline

The two objectives of this dissertation—(1) to create an overview of stakeholder interactions that influence the development and implementation of technological innovations, and (2) to gain a better understanding of how stakeholder interactions can support legitimacy and contribute to more socially robust innovations—are addressed in five empirical studies. These studies focus on different technological innovations, include various types of stakeholders and are based on several research methods. In Table 1.1 the key aspects, in terms of involved stakeholders, type of interactions, purpose of these interactions and type of innovation, addressed in each study are displayed.

Chapter 2 contributes to the first objective as it provides an overview of the stakeholder interactions that are needed for the development and implementation of technological innovations from an entrepreneurial perspective. The study is based on 24 semi-structured interviews with CEO/founders of a technological start-ups working on different innovations in the health, sustainability, safety, high tech systems and materials (HTSM) and ICT sectors. It uses the functional approach of the TIS framework to analyse and categorize these processes from an entrepreneurial perspective. A wide variety of stakeholder interactions are relevant and necessary in the innovation process, such as explaining and framing the technology, networking, collaborating with partner organizations, and adapting to the societal environment. The interactions can be connected to five functions of the TIS framework, with resource mobilization and legitimation most frequently being referred to. This is followed by entrepreneurial experimentation, market formation, and, to a lesser extent, knowledge development.

Chapter 3 contributes to the second objective and reports on a media-analysis about technology legitimation of genetically modified (GM) food in the public discourse. It describes how the four pillars of legitimacy—normative, cognitive, regulative and pragmatic—can be used as a framework for analysing technology legitimation in the public discourse. The results show that the public debate on GM food was predominantly negative, with a strong focus on the normative pillar, followed by the cognitive pillar. Emotional rhetoric exceeded the knowledge and understanding of GM food. Furthermore, the regulative pillar (rules and regulations) and the pragmatic pillar (utility of the technology) were less addressed. This study suggests that legitimacy should be approached in a multidimensional way based on all four pillars, and it shows that these pillars can serve as a framework for analysing and comparing legitimacy of different technologies in the public discourse.

Chapter 4 describes a mixed-methods approach to obtain a better understanding of how homeowners and tenants perceive the transition towards sustainable heat in the Netherlands. This study contributes to the first and second objective, because it provides several insights for local governments on how to create acceptance and legitimacy for the transition towards sustainable heat among residents, including the themes that should be addressed in the communication about the transition, stakeholders that could be involved in the communication and in the transition, and the ways of engaging both homeowners and tenants in the transition.

Chapter 5 describes the potential of engaging citizens in the development of nanotechnologies for healthcare applications aiming at the creation of socially robust innovations, and contributes to the second objective. The chapter describes the results of eight extensive focus groups and shows that citizens are able to contribute to various technology aspects, including implementation, use, system, development, design and communication. Most of their suggestions are based on concerns of the potential effects of the technologies and can be related to values such as well-being, autonomy and privacy of data.

Chapter 6 describes the final empirical study of this dissertation about how co-creation with different types of stakeholders, including researchers, businesses, policymakers, civil society organizations and citizens, can support RRI. Co-creation is a form of engagement where different types of stakeholders jointly generate meaning and value. The analyses of three co-creation sessions on nanotechnology applications for health suggest a trade-off between a legitimate innovation process and added value of the innovation based on inclusion, anticipation, and adaptation. This study contributes to the second objective, because it reflects upon how stakeholder engagement can enhance legitimacy and lead to more socially robust innovations.

Finally, **Chapter** 7 reflects on the findings and conclusions of the separate studies. This chapter elaborates on how these findings meet the two objectives of this dissertation and reflects on the role of communication in innovation processes.

Table 1.1. *Overview of the key aspects per chapter*

	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6
Stakeholders involved	Entrepreneurs, Policymakers, investors, businesses, media, knowledge institutes, end-users, citizens	Traditional media, general public	Local governments, end-users, housing corporations, civil neighbourhood councils, net distributor, energy companies	Citizens, Researchers, developers, policymakers	Researchers, businesses, policymakers, CSOs, citizens
Type of interactions	Communication processes and strategic innovation processes	Framing and explaining the technology	Providing information and public engagement	Public engagement	Co-creation
Purpose	Development and implementation of innovations	Creating legitimacy	Creating legitimacy and implementation of innovations	Developing socially robust innovations	Creating legitimacy and developing socially robust innovations
Technology	Technologies for health, safety, sustainability, ICT, HTSM	GM food	Sustainable heating technologies	Nanotechnologies for health	Nanotechnologies for health

2

Technological start-ups in the innovation system: An actor-oriented perspective

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2.1 Introduction

The Technological Innovation Systems (TIS) perspective has become a dominant approach in studying the dynamics of the development, utilization and diffusion of new products and technologies. TIS adopts a holistic perspective, in which a technological innovation is seen as a 'network of agents interacting in a specific industrial area under a particular institutional infrastructure' (Carlsson & Stankiewicz, 1995, p. 49). These agents include diverse academic, economic and governmental actors that interact within networks (e.g., technology consortia, learning networks and public-private partnerships), shaped by institutions (e.g., culture, norms, laws and regulations) (Bergek, Jacobsson, Carlsson et al., 2008). Although TIS has shown its relevance in various empirical studies by contributing to the understanding of the development of different innovations, it is still in development (Suurs & Hekkert, 2009).

In fact, several areas of TIS are rather underdeveloped. Firstly, TIS is primarily used as an analytical framework to inform policy making. However, some scholars acknowledge that it might be useful for the management domain as well, as entrepreneurs play a pivotal role in the innovation processes and even might be able to overthrow and change structures around them (Hekkert et al., 2007; Planko et al., 2016). Secondly, TIS has mostly been used as a top-down approach, but as Markard and Truffer (2008b) have shown, a bottom-up approach from an actor-based perspective provides new and useful insights into the influence of a particular actor-group on the innovation system. Thirdly, the TIS-literature leaves room for further specification of the interactional processes that shape technological innovations. Although these interactions are key to understand the innovation system, a detailed understanding of them remains underexplored (Bergek, Jacobsson, & Sandén, 2008; Binz et al., 2016).

In order to further develop TIS as an analytical framework, the aim of this study is to investigate to what extent the functional approach of TIS is a useful framework to identify the interactional processes of technological start-ups involved in generating (technological) innovations. As technological innovations are increasingly initiated by creative enterprises (Groen & Walsh, 2012) and technological start-ups play a key role in the economy (Maes & Sels, 2014), this study focuses on this actor in the innovation system.

2.1.1 Functional approach of TIS: From policy to strategic management

The functional approach of TIS emerged in the beginning of the 21st century and saw a rapid increase in attention since its specification by Bergek, Jacobsson, Carlsson et al. (2008). The functional approach aims to clarify the dynamics of the system in which the interactions take place and is used to identify (potential) factors that may hinder or promote the development of technological innovations (Wieczorek & Hekkert, 2012). Within such a system, seven functions can be distinguished: resource mobilization, market formation, legitimation, entrepreneurial experimentation, knowledge development, influence on the direction of search, and development of externalities (Hekkert et al., 2007; Bergek, Jacobsson, Carlsson et al., 2008). These functions have been mainly formulated on an abstract level, as they are used as heuristics to understand the dynamics of an individual innovation, rather than as guidelines that prescribe how a system optimally functions. An improved understanding of the functions in TIS is important, because of the consequences it can have for producers and customers in a particular field, as well as for policy makers and society at large (Markard & Truffer, 2008b; Binz et al., 2016).

The functional approach of TIS has been mainly applied in the policy domain as an analytical framework. Jacobsson and Bergek (2011) state that "the key contribution of the innovation system analyses is (...) that it provides policy makers with a tool for identifying system weaknesses" (p. 43). Furthermore, Markard and Truffer (2008b) argue that the functional approach makes it possible to assess innovation systems, and "on the basis of system comparisons, scholars are finally able to arrive at policy recommendations" (p. 601). By analysing the functions of TIS, policymakers can identify key policy challenges, and assess whether inducement or blocking mechanisms should be applied.

Although far less explicit and elaborate than in the policy domain, a connection between TIS and the management domain was made in the same period as well. For example, Bergek et al. (2008d) and Markard and Truffer (2008b) underline the importance of managerial perspective in the innovation system and relate literature on innovation systems to literature on business studies and innovation management. Only recently, a first conceptualization of TIS as strategic management framework was made by Planko et al. (2016), who investigated to what extent entrepreneurs recognized the functions of TIS in the development and implementation of their technological innovation. Indeed, the entrepreneurs acknowledged the importance of all functions in their daily work, although the prominence of specific functions varied. However, they only focused on one sector (smart grids), and did not systematically address the interactional processes involved in the functions. To further scrutinize the applicability of TIS in the management domain, these processes should be the starting point, rather than entrepreneurs' recognition of the functions.

2.1.2 An actor-oriented perspective

Much progress has been made towards the identification of general conditions for a successful system performance at the macro- and meso-level of TIS. This includes the identification of various actors that are involved in the generation and diffusion of technological innovations, such as firms along the whole value chain, universities and research institutes, public bodies, interest organizations, venture capitalists, and organizations deciding on standards (Bergek, Jacobsson, Carlsson et al., 2008). While the involvement of these actors is mostly described top-down, "considerably less effort has been devoted to systematically explore the link to the micro-level of innovation actors" (Markard & Truffer, 2008b, p. 444). Nonetheless, an actor-oriented analysis from a bottom-up perspective can provide insights into the role of different actor-groups in the development of technological innovations (Markard & Truffer, 2008b). Of the various actor-groups included in TIS, especially the importance of entrepreneurs has been emphasised in innovation literature (Hekkert et al., 2007). According to Markard and Truffer (2008b), business units within larger companies, but also single-business companies which operate exclusively in the innovation field are a key actor-group in generating and diffusing innovations.

Several attempts have been made to identify the interactions that take place within a particular function (e.g., Bergek, Jacobsson, Carlsson et al., 2008; Bergek, Jacobsson, & Sandén, 2008), but they have been described in an illustrative way and not systematically. The main reason for this is that most interactions and stakeholders are described top-down and from a holistic point of view in the TIS literature. Therefore, in this study we will investigate the interactional processes of technological start-ups in the innovation system from an actor-oriented perspective.

2.2 Method

2.2.1 Design and instrument

To unfold the interactional processes, in our study we used the qualitative empirical research cycle based on an inductive approach. As our research aims to further specify the interactional processes of one specific actor-group, this approach was most appropriate. To examine whether TIS indeed is applicable in the management domain we did not explicitly direct the interviewees towards (the seven functions of) TIS to avoid a bias. Instead we asked them about their experiences with the development of their product or technology, and about their interactions with various stakeholders during this process.

The interview scheme consisted of four parts. In the first part, we asked the interviewees to explain the technology or product they were developing or implementing, along with its possible applications. We also asked them about the possible impact of the innovation, as this may influence the interactional processes (Greenacre et al., 2012; Dijk et al., 2013). Secondly, we showed interviewees four different developmental phases of a technological innovation (discovery, incubation, acceleration, and commercialization), derived from the literature on new product development (Pullen et al., 2009; Story et al., 2010). These phases were useful, as they helped interviewees to describe the developmental process of their innovation step by step. We first asked the interviewees to describe in which phase they currently found themselves with their technological innovation, after which we asked them to describe how the innovation evolved through the different phases. Thirdly, we asked the interviewees to point out the stakeholders that were important for the development and implementation of the technological innovation. In order to do this, interviewees had to first write down the stakeholders per phase. We then showed them a list of possible stakeholders, derived from the TIS perspective (c.f., Bergek, Jacobsson, Carlsson et al., 2008) and asked them if any stakeholders were missing. Subsequently, we asked the interviewees to explain why the various stakeholders were important, how they interacted with them, and how the stakeholders affected the developmental process of their technological innovation.

The interview scheme served as the general structure for the interviews, but as the interviews were semi-structured, other questions for clarification were asked as well. The

interviews took between 40 and 90 minutes. All but two interviews were conducted in a face-to-face setting. The other two were conducted via Skype for logistical reasons. The interviews were recorded and transcribed. All interviewees , except for one, agreed with being recorded. In the exception, the interviewer made notes of the answers during the interview.

2.2.2 Participants

For the interviews, we selected founders of innovative technological start-ups. In order to get a clear picture of the interactional processes around a technological innovation, it was important to carefully select the start-ups. We cooperated with a consortium between a technical university, a university of applied sciences, a municipal board, and the provincial government in the eastern part of the Netherlands. This consortium was created to valorise and accelerate knowledge and innovations, and gave us access to nearly all spin-offs located in the region (a database with more than 900 spin-offs from both the technical university and the university of applied sciences). We selected the most innovative spin-offs, based on database analysis and content analysis. To facilitate comparability, we made a first selection based on sector and type of technology (among others: nanotechnology, ICT, sensor technology, and membrane technology), and type of spin-off (research and patent based). This narrowed down the sample to 142 start-ups. For these remaining 142 start-ups, we conducted a content analysis of the product information on their websites. We first examined whether these were actually working on their own product or technology. Subsequently, we examined whether the innovation included the development of a new technology or a new application of an existing technology. In total, 38 start-ups met these criteria.

Based on the area of application of the product or technology, we divided the start-ups into five categories: health, safety, sustainability, ICT, and other. We contacted these start-ups via the consortium's managing director, by e-mail and phone. In total, 24 start-ups agreed to participate.

2.2.3 Analysis

Following the Grounded Theory approach (Corbin & Strauss, 2008), we first inductively analysed the results by selecting the text parts in which any kind of interaction was mentioned. These text parts formed the units of analysis. They consisted of three to 20 lines and described one kind of interaction. After a first analysis, we used the seven functions of TIS to link them to the interactional processes, in a second round of coding. We found that the processes which seemed rather random and disorganized in the first round, showed a clear structure when we linked them to the seven functions.

Hence, the codebook consisted of the seven key processes of TIS: resource mobilization, market formation, legitimacy, entrepreneurial experimentation, knowledge development, influence on the direction of search, and development of externalities (Table 2.1). Using these seven codes, we could code a large majority of the transcribed interviews (most introductory parts could not be coded, as they explained the technical features of the product or technology). After coding 10% of the text units, a second coder independently coded the same units using the codebook. This resulted in a Cohens kappa of 0.65, which is considered to be a good agreement since the codes are rather abstract and include various topics. Based on the codebook, one coder analysed the remaining text parts.

Table 2.1 *Description of the functions of TIS (derived from Bergek, Jacobsson, Carlsson et al., 2008)*

Functions	Description
Resource mobilization	Mobilization of competence/human capital, financial capital, and complementary assets, such as investments, human resources, and changes in supply resources and infrastructure for the purpose of the development of the innovation
Legitimation	Getting social and institutional acceptance of a product/technology by counteracting resistance to an innovation and creating incentives
Entrepreneurial experimentation	Finding and trying new applications and markets for a product/technology, including the social learning process people working on the innovation go through
Market formation	Development of the market around a product/technology and how innovators approach it
Knowledge development	Development of scientific, technological, production, market, and design knowledge of an innovation by creating knowledge through R&D programs and exchanging knowledge through networks
Influence of direction of search	Influence of visions, expectations, and beliefs in growth potential and relevance of the product/technology on the development of it
Development of externalities	External developments in society that can possibly influence the technology, such as crises, structural political developments, and demographic developments

2.3 Results

In this section, the results of the interviews are discussed, following the seven functions of TIS . The order of the functions is based on how frequently they were mentioned by the interviewees.

2.3.1 Resource mobilization

Most interviewees considered resource mobilization to be an important function in the development of technological innovations. Of all 1136 text parts that were coded, 351 parts were about resource mobilization. The resources the interviewees discussed can be divided into the categories money and manpower.

2.3.1.1 *Money*

Money was by far the most frequently mentioned resource. Most interviewees emphasised the importance of money as a precondition for the development of a technological innovation. Money can be collected through public funding in the form of subsidies and public loans, or through private investments. Many interviewees mentioned the difficulties and obstacles in the process of getting money.

Firstly, finding the right subsidy program or attracting the right investor was an issue. Due to a fragmented subsidy system that is divided into different layers (regional, national, and European), programs and themes, and offered at different times, interviewees found it hard to figure out which program fits their innovation best. Interviewees who collaborated closely with the university and had a network with officials in regional and national politics mentioned that these actors were important sources of information for upcoming programs. This is exemplified in the following quote: *"It is just important that you find the right subsidies at the right moment and that you know the right people. Due to our network, we often know about a subsidy program before it even is publicly announced"* (Interviewee 16, Energy). When attracting private investors, finding the right one was an issue as well. This is mainly because innovators were not looking for an investor solely for money, but also for advice and coaching. They emphasised the importance of having an investor with knowledge about the potential markets and entrepreneurial processes. For example, a respondent stated: *"They had found us. And yes, we immediately felt good about it; they knew the market. We did not just want money, we wanted money from people who really knew the market"* (Interviewee 7, ICT). Furthermore, a number of interviewees mentioned that there are many 'wrong' private investors who only focus on short-term profits; not taking any risks and demanding too much influence on the decision-making process. This would not benefit their innovation.

Secondly, almost all interviewees were very critical about the application procedure for subsidies, which they found bureaucratic and time-consuming. The process was a time-consuming process, because they had to fill out many forms to explain the technological features and possible applications. Having the right communication skills to explain the technology in an understandable way is crucial. Often, members of the screening committee did not have any knowledge about the technological details of the innovation, and were focused on the problems in a specific sector or area. In practice, this meant that innovators should not elaborate on technological features, but instead, write the application from a problem-based perspective. This is the other way around for private investors, who are especially interested in the solutions.

Finally, even when the right program was found and the application criteria were met, the problem occurred that innovators still depended on public officials who were responsible for the screening process. Interviewees emphasised the importance of having a large network and getting media-attention, because being top of mind among public officials or knowing someone of the screening committee was important to get approval for the subsidy. For example, one of the interviewees stated that *"knowing people from the screening committee is very important. They often look at the name of the consigner; at the applicant and his partners"* (Interviewee 23, Safety). Another interviewee said: *"We only got approval for the public financial and business support for innovative start-ups, because we had some media attention. Without this media attention, we would probably never have gotten approved for the program"* (Interviewee 12, ICT).

2.3.1.2 Manpower

Besides money, the team involved in the development of the innovation is crucial for its success. All interviewees explicitly mentioned the importance of attracting the right people to work with and for them. This is not only essential for the development of the innovation, but also for attracting investors, and later on, for communicating with the market. Finding skilled employees that fit the team, both on a management and on a lower level, was seen as a challenge by quite some interviewees. They mostly found them through their own network.

Besides having the right managing team, manpower was needed for the development of the product. Many interviewees emphasised the usefulness of being located in a region with a technical university, where students could be recruited to work for them. Having a good connection with professors and student associations gave them the opportunity to find the best students.

2.3.2 Legitimation

The second function that was frequently mentioned (227 times) was the process of 'legitimation'. When interviewees talked about legitimation, they either mentioned creating incentives for the development of an innovation or counteracting resistance that might hinder it. Creating incentives or 'enthusiasm for the technology' in society and among public policymakers was important, as it could help in the process of resource mobilization and market formation. Resistance mostly involved legal barriers and negative attitudes towards the technology in society and among potential end users. Interviewees mentioned various interactional processes to create incentives or counteract resistance.

Choosing the right applications of the technological innovation is one way to create positive incentives. By choosing applications that fit the needs of society and policymakers, it is easier to mobilise means (see Resource Mobilization) and get support for the innovation process. As one interviewee stated: *"In the beginning, we focused on cooling, but we soon changed to heating (...) because heating has a much larger market in Western Europe. It might be more complex on a technological level, but you've got more parties that are interested... it is easier to get subsidies."* (Interviewee 16, Sustainability)

Other founders changed their product and production process to become more sustainable. They did not do this to improve technical features of the product, but to get access to other subsidy programs and to get societal approval. As one respondent explained: *"We chose to make [the product] of a material that is formally approved by the European Commission (...). With these elements, we answer societal needs and we try to fit in the circular economy program"* (Interviewee 21, Sustainability). However, only finding the right application was often not enough for creating legitimation. Interviewees underlined the importance of generating awareness of the positive features and/or problems that could be solved with the technology. This was especially the case for start-ups in the health, safety, and sustainability sector. Through positive media attention, networking events, and company visits, attempts were made to create this awareness. This was done on a societal, client, or public-official level.

Several interviewees mentioned the regulations around certification of the products as a resistance to counteract. In several sectors (e.g., health, energy, and safety), certification or compliance with established rules was necessary to bring the product to the market. However, the interviewees argued that their product was too innovative to meet these rules. One of them mentioned: *"The only thing that we are doing is getting our technology included in the regulations. We have to get included in the regulations, so people can use our product legally"* (Interviewee 17, Other). When this was the case, the innovators tried to change the legislation around the technology by themselves. They sometimes did this by trying to get invited to governmental advising committees when a new certification standard was drawn up, or by lobbying among public officials in order to change the regulations. Some interviewees mentioned that it was important to already start such lobbying activities in the early phases of the developmental process. An illustrative phrase mentioned by one of the interviewees: *"I think we were too late with influencing the government, way too late. (...) I've joked around, but I do think that there's a truth in it, that I should have hired a PR person in The Hague [where the Dutch government is located]."* (Interviewee 1, Safety)

The main reason was that it is easier to get legitimacy of a technology in the beginning of its development than of a product that has already been commercialised. It is harder for public administrators to modify regulations for organizations that are already operating on the market than for organizations that are still developing an innovation, since helping the former would influence their competitiveness.

Another resistance mentioned was created by potential end users. Some innovations in the health, ICT, sustainability, and safety sector required a different way of working off the end user. Examples of different end users are farmers, accountants, building experts, people working at water-treatment companies, energy distributers, and telecom companies. These groups had to be convinced of the benefits of working with the new technology. One way to do so was through education, by providing workshops or lectures for the target group. Another way was by having ambassadors (e.g., important clients, professors, or experts) support the innovation and spread the word. Cooperating with third parties or branch organizations helped as well. One of the interviewees worked with veterinarians to convince farmers of the added value of the innovation. Media attention or winning awards also helped to get legitimation among end users. A quote of one of the interviewees illustrates this, *"at one point, we won an award. The people then thought: "These guys have won an award, how is that possible? The technology must work then". We then won another award after which they definitely believed our product would work"* (Interviewee 21, Sustainability).

2.3.3 Entrepreneurial experimentation

The third function that was frequently mentioned (215 times) was 'entrepreneurial experimentation'. This function includes finding and trying new applications and markets for the technology. The interviewees often mentioned two points of interests in this process. The first was that for every development within a technological innovation, the innovator goes through the same entrepreneurial process. The second characteristic was avoiding tunnel vision during the developmental process, which could be devastating for the innovation.

Since there is a similar entrepreneurial process for every innovation development, experience with and knowledge about the process is extremely useful. However, most innovators had neither the entrepreneurial skills nor the experience required to smoothly manage the development of the innovation. Therefore, it was crucial to bring in help from others. This was most often done by either consulting other innovators from the network, or by attracting a managing partner (see Resource Mobilization). Furthermore, gaining support through coaching programs from universities or regional administrations that try to valorise knowledge into viable products was mentioned as helpful. Respondents also mentioned that it was important to constantly review the entrepreneurial process and approach other parties for advice.

Another important aspect mentioned by interviewees about the entrepreneurial process is that being flexible and being informed about what is happening in the environment is essential for good entrepreneurship. Flexibility is important for getting resources (especially money, see Resource Mobilization), but also for developing the technology. This is exemplified in the following quote: *"For a start-up to be successful, you have to be good in the entrepreneurial process, which means that you cannot merely focus on the technology. I always say entrepreneurship is a managed coincidence. You come across things that you have to fit in your developmental process. It is impossible to set out the whole path in advance. It requires a certain degree of flexibility."* (Interviewee 18, Sustainability)

2.3.4 Market formation

Answers regarding 'market formation' were mentioned less often (168 times). When interviewees discussed market formation, they mainly talked about how to approach the market and not about its characteristics and developments. Approaching the market with a new technology, which in most cases involved a rather radical innovation, is a difficult process. Having a large network of potential clients, collaboration partners, or investors, and advanced communication skills to sell the unfamiliar innovation were of utmost importance. This was illustrated by one of the interviewees as follows: *"Not having a network of potential customers or investors is something that often goes wrong. You see, the product does not sell itself"* (Interviewee 16, Sustainability). Three strategies were mentioned to enter the market: approaching the market on their own; developing the technology as far as possible and then selling it to a dominant player in the market; and collaborating with a larger partner.

The majority of the interviewees planned to approach the market themselves. All of them explained the importance of giving a clear explanation of the technology and its working principles. Additionally, many of them stated that, in order to be able to tell a convincing story, a clear focus with regard to the application of the technology was needed. One interviewee explained, for example: *"You can actually apply the technology in various ways, but you have to start with one thing. Focus is very important for small technology oriented businesses, especially for start-ups"* (Interviewee 1, Safety). Furthermore, the interviewees who intended to bring the product to the market on their own emphasised the importance of having a large network.

Some of interviewees, especially in the health and sustainability sector, did not have the intention to bring the innovation to the market themselves. They thought it was too hard to enter a market where a couple of large players are dominant. Instead, they tried to develop the innovation as much as possible and then sell it to a large competitor. One interviewee illustrated it as follows: *"The final goal is to have an exit and to sell our product to a large company. Why? Because in these times, you can't do it on your own anymore. It all goes too fast to approach the market yourself"* (Interviewee 3, Health).

There were also innovators who wanted to take part in the commercialization phase, but recognized they could not do it alone, as they lacked a large network of potential clients. Therefore, they collaborated with larger partners who did have this network, such as distributors. Mostly, these partners had already been attracted in an early phase of the developmental process. As these partners had a clear perspective on the needs of the potential clients, they could influence how the innovation was being developed. Attracting partners for collaboration was comparable to attracting private investors (see Resource Mobilization): Both the innovation and the innovator had to be presented convincingly.

2.3.5 Knowledge development

Another function that was mentioned less often (107 times) is 'knowledge development'. This function concerns developing and sharing knowledge, either about the technology or about entrepreneurship. For knowledge development on both subjects, knowledge institutes (e.g., universities and thematic campuses) and regional administrators were seen as important.

An aspect that was often mentioned was how the knowledge about the 'idea' of the technology had evolved. Many technologies started as a theory or idea in PhD trajectories at the university. These were then patented and further developed into a commercialised product. Motivated PhD students or entrepreneurs valorised these innovations by trying to develop them into a working product. However, the interviewees stated that many innovations that got patented had not been developed further due to a lack of motivated people.

The university, together with the regional government, played a vital role in the process of knowledge sharing between technological start-ups. Many interviewees embraced the collaboration between university, valorisation organizations, and regional administrations. They also explained that this often led to the specialization of a particular technology or area, which resulted in various regional clusters in the Netherlands (e.g., energy, water, HTSM). Although most interviewees agreed that these clusters may help to get legitimacy within a region, some were also critical of it. They criticized the lack of collaboration between the clusters, as the prime goal of focusing on a cluster is getting legitimacy and resources from the national and European government, instead of creating a framework of knowledge sharing.

Besides the need of sharing knowledge about the innovation with others, almost all interviewees underlined the importance of exchanging information about the entrepreneurial process (see Entrepreneurial experimentation). In this regard, the university and regional administration again played an important role by offering valorisation programs and creating network events. Additionally, informal networks were mentioned as an important aspect for knowledge development: "*We go to various network events, where you can meet other entrepreneurs. You talk with them about your own business and get feedback from them, which is very useful*" (Interviewee 6, ICT).

2.3.6 Influence of direction of search and development of externalities

Two functions that were mentioned far less often than the others were 'development of externalities' (32 times) and 'influence of direction of search' (41 times). Both are external processes that may hardly be influenced by the entrepreneurs.

Externalities can be developments in society or sectors that have a direct or indirect influence on the innovation process. Changes in policy were often mentioned as an external influence. References to particular changes varied between the interviewees, depending on the technology and the sector. One interviewee explained, for example, how new regulations had tightened the budget of hospitals, which impacted on the potential market. Another interviewee emphasised that budget cuts have caused retrenchments in the innovation climate in the Netherlands since the economic crisis. The lack of a clear vision of Dutch politics on sustainable energy was also mentioned as a negative externality that influenced the innovation process. Nevertheless, several interviewees did mention the rapid growth of innovations in the world and the mutation of the organization around it. They emphasised that whereas a few large companies were mostly responsible for the development of technological innovations in the 20th century, SMEs are nowadays involved in the development. One interviewee said: "*Small businesses, that's where the new technologies are coming from. They can take risks and they are innovative*" (Interviewee 18, Sustainability).

Where externalities mostly have an influence in the later developmental phases of an innovation, the process of 'influence of the direction of search' impacts the development in its early phases. This was mostly mentioned as an explanation of how the interviewees came to the idea and business proposal for the technological innovation. Influence of direction of search includes factors such as challenges in society (e.g., pollution of drinking water), demands from clients or the market, and possibilities of technological features (e.g., the lab-on-a-chip technology).

2.4 Discussion and conclusion

In this study the aim was to explore whether TIS is a useful framework to identify and understand the interactional processes that are important for technological start-ups involved in the development of technological innovations. Our findings show that TIS indeed is a useful framework for the strategic management domain. The functions of TIS provide a clear structure to understand the dynamics in which technological start-ups are involved in the process of generating a technological innovation.

'Resource mobilization' was the most prominent function in the development of a technological innovation. The interviewees especially emphasised the attainment of subsidies and investments in this regard. Without money an idea can never be developed into a product or technology. Moreover, interviewees mentioned that several great patented ideas or technologies could not be further developed due to a lack of funding. Additionally, 'legitimation' was seen as an important function. On the one hand to create incentives that advance the process of resource mobilization, on the other hand to remove barriers and shape the institutional framework in a positive way. 'Entrepreneurial experimentation' was frequently mentioned as well. The interviewees emphasised how a learning curve could be developed by experience and trial and error in this regard. Furthermore, they stated that flexibility in the development and application of the technology was essential.

Table 2.2 presents the interactional processes and stakeholders that could be linked to the different functions. Five of the seven functions contained interactional processes that could be related to them, of which 'networking' was mentioned most often. In the TIS literature the components of a system are identified as actors, networks and institutions. From this research it becomes clear that technological start-ups actively try to be part of various networks in order to advance the development of their innovation.

Furthermore, 'framing and explaining technology' and 'approaching the media' can be related to both resource mobilization and legitimation. This is in accordance with the findings of Petkova et al. (2013), who found that start-ups try to get media-attention through sense-making activities in order to gain legitimation for their innovation. Subsequently, this legitimation process helps them to get investments from investors. The interviewees emphasised that framing and explaining a technology should be different to different stakeholders. For public officials, a technology should be explained from a problem-based perspective, but for investors, it should be explained from a solution-based perspective. Additionally, it is important to prove the reliability and the working principles of a technology for potential clients, and the newsworthiness for the media. Nevertheless, in all frames, an innovation should be explained straightforwardly and understandably for the layman.

Table 2.2 *Interactional processes and stakeholders linked to the functions of TIS*

Functions of TIS		
Resource mobilization	**Interactional processes:**	Networking, framing and explaining technology, writing applications, approaching the media
	Stakeholders:	Screening officials, investors, knowledge institutes, media
Legitimation	**Interactional processes:**	Networking, framing and explaining technology, approaching the media, lobbying, collaborating with other parties, strategically choosing application and sector
	Stakeholders:	Policymakers, investors, partner organizations, media, end users, citizens
Entrepreneurial experimentation	**Interactional processes:**	Networking, collaborating with other parties, getting advice
	Stakeholders:	Fellow entrepreneurs
Market formation	**Interactional processes:**	Networking, framing and explaining technology, strategically choosing application and sector, timing of communication
	Stakeholders:	Investors, partner organizations, competitors, potential clients
Knowledge development	**Interactional processes:**	Sharing knowledge, collaborating with other parties
	Stakeholders:	Regional government, knowledge institutes, valorisation organizations, fellow entrepreneurs

Another interactional process that appeared multiple times is 'collaborating with other parties'. This collaboration is needed in order to gain legitimation, develop knowledge, and learn from entrepreneurial experimentation. In various earlier studies the importance of collaboration was also underlined. Bergek, Jacobsson, and Sandén (2008), for example, concluded that entrepreneurs should form broader coalitions in order to obtain legitimacy for their innovations. Furthermore, Bouncken and Krauw (2013) underlined how collaboration is crucial for SMEs to obtain technological progress. Through collaboration SMEs gain access to additional resources and benefit from knowledge spill overs.

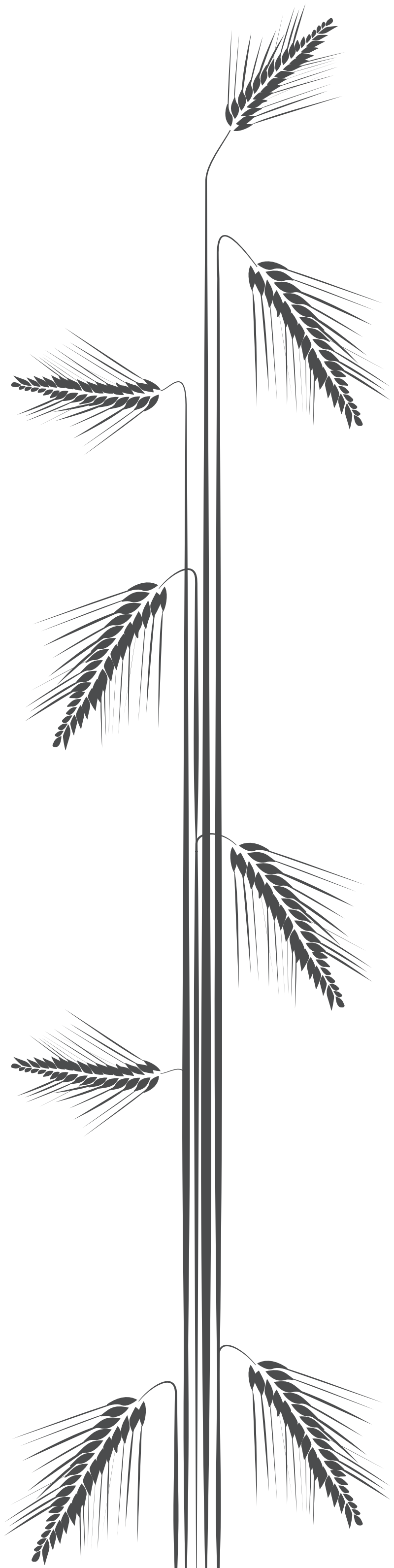
No interactional processes could be linked to the functions 'influence of direction of search' and 'development of positive externalities'. Even though interviewees sometimes mentioned these functions as important for the context in which they were operating, they did not refer to concrete interactions in this regard. The main reason for this is that both are external processes that cannot be directly influenced by the innovators themselves.

Besides the interactional processes, interviewees also mentioned the stakeholders they were interacting with (see Table 2.2). The government, investors, partner organizations (e.g., distributers, knowledge institutes), and clients or potential end users were mentioned as important stakeholders. Remarkably, the role of stakeholders can differ between processes. The government, for example, on the one hand distributes financial resources that are necessary for the development of a technological innovation (through subsidies, both on a regional and a national level), but on the other hand, serves as a gatekeeper and might hinder technological innovations with its regulations. Additionally, regional governments are an important catalyst for knowledge sharing. This finding is in accordance with Story et al. (2013), who found that actors involved in the development of technological innovations perform various roles.

In conclusion, TIS appears to be a promising framework for the strategic management domain. though interviewees were not directly asked about the seven functions, the answers they gave could be directly linked to them. By applying an actor-oriented perspective we were able to get a clear picture of the interactional processes start-ups are involved in when generating a technological innovation. With our study, a next step is made in embedding TIS in the management domain. Whereas Planko et al. (2016) found that TIS provides useful insights for the entrepreneurs, we found the value of TIS as a managerial analytical instrument for a great variety of sectors. Furthermore, with our focus on the interactional processes that take place within the functions of TIS, we were able to go beyond the retrospective contribution of TIS and develop a practical instrument for entrepreneurs.

Some limitations of this study should be acknowledged. Firstly, we used the seven functions of TIS as separate codes. Within the TIS literature, these functions are less independent and show some overlap. Sometimes, interactional processes matched multiple functions, but we were always able to detect the leading function by looking at the goal of the interactional process. Secondly, due to our focus on technological start-ups, it is hard to make generalizations to other types of entrepreneurs in this regards. One might expect that for large businesses 'resource mobilization', is of less concern. Instead, 'legitimation' might be more important.

Finally, as the actor-oriented perspective on TIS turns out to be promising, other relevant actors could be included in future research as well as the prominence and the nature of the functions of TIS might considerably differ among these actors. As shown in this study, taking an entrepreneurial perspective, several stakeholders play a pivotal role within the functions. Especially the perspectives of these stakeholders could be taken into account.



3

Technology legitimation in the public discourse: Applying the pillars of legitimacy on GM food

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3.1 Introduction

As technological innovations can have a major impact on society, it is important to create legitimacy among the general public. Legitimacy can be described as "being perceived as desirable, proper, and appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman, 1995, p. 574). In the case of radical innovations, such as genetically modified (GM) food, proponents have to spend considerable efforts on creating legitimacy as they are often received with major doubts about their utility due to their 'liability of newness' (Binz et al., 2016; Petkova et al., 2013).

The public sphere is an important domain for the legitimation of technological innovations. It functions as a core element in modern democracies, enabling citizens to access information, observe decision-makers, form judgements of societal developments, and articulate their views and opinions (Gerhards & Schäfer, 2009). This collective process of sense making is reflected by the public discourse. Mass media play a pivotal role in the public sphere, as they are both reflecting and influencing the public discourse through their selection of topics and applied frames (Malett et al., 2017). In the context of technological innovations, positive expectations dominating the public discourse are an indication of high legitimacy, while the articulation of negative expectations or no reference at all is an indication of a lack of legitimacy (Bergek, Jacobsson, & Sandén, 2008).

Legitimacy is not a static phenomenon and should be treated as a multi-dimensional variable with different characteristics and dynamics that might change over time (Binz et al., 2016). In the institutional domain, scholars have extensively studied the dynamics of legitimacy (e.g., Johnson et al., 2006; Scott, 2013; Suchman, 1995). From these studies, it has become clear that four pillars of legitimacy can be distinguished, the cognitive, normative, pragmatic, and regulative pillars, all of which reflect a different dimension of legitimacy. Binz et al. (2016) used these four pillars as a framework for technology legitimation of potable water reuse among various stakeholders. In the context of renewable energy technologies for transport, Bergek, Jacobsson, and Sandén (2008) emphasised that when advocates of renewable technologies are not able to influence legitimacy in one pillar (e.g., regulative), they can try to influence the other (e.g., normative).

The aim of this study is to apply the pillars of legitimation as a framework for analysing media articles, to enhance our understanding of technology legitimation in the public sphere. By developing such a framework, the legitimation processes of different technological innovations can be compared. As this research is explorative in nature, we conducted a case study focusing on GM food.

3.1.1 The case of GM food

GM food has been the subject of public controversy ever since its first application in the 1970s (Gutteling et al., 2006), which makes it an interesting subject for studying the legitimation processes. GM foods are food products containing, consisting of, or produced from genetically modified organisms (GMOs). GM crops and foods are believed to offer a range of benefits, including lower pesticide costs, less environmental pollution from pesticides and herbicides, higher productivity, and new crop varieties to alleviate hunger in developing countries (Gaskell et al., 2004). However, much opposition has risen from organizations, interest groups, and the general public concerning environmental risks, food safety, and monopolising tendencies of big firms (Frewer et al., 2004; De Jong et al., 2000). In the Netherlands, the general public is rather ambivalent towards biotechnology, without extremely negative or positive reactions. Although there has been a declining support for the implementation of GM food (from 59 percent in 1996 to 30 percent in 2010), the Netherlands is still among the European countries with the highest support, along with the United Kingdom, Portugal, Spain, Ireland, and Denmark (European Commission, 2010). Nevertheless, there seems to be a lack of knowledge among the general Dutch public in regard to GM food and crops (Hanssen et al., 2015; Lucht, 2015); which, as Gaskell et al. (2004) argued, could lead to emotional and irrational opinions.

3.2 Theoretical background

3.2.1 Public discourse

Legitimacy is embedded in widely shared cultural beliefs from the surrounding society, therefore it is important to consider the public discourse. With regard to technological innovations, Bergek, Jacobsson, and Sandén (2008) found that public discourse is one of the shaping processes of legitimation. As actor-groups may have different expectations, they compete with each other to influence the public discourse by using different frames (Geels & Verhees, 2011). Consequently, these competing frames are reflected in the public discourse and affect attitudes, feelings, opinions, and actions of other relevant actors. These actions include mobilizing resources from investors and policy makers, political protections, and support from the general public (Jansma et al., 2017).

In an attempt to gain insights into legitimation processes, various innovation scholars have studied the public discourse on technological innovations by means of media analysis (e.g., Markard et al., 2016; Smink et al., 2015; Zschache et al., 2010). Through deliberative coverage of news, mass media have the ability to set the agenda for public debate. In particular, traditional media are seen as an authoritative source of information, thereby creating social facts (Malett et al., 2017). Journalists not only set the agenda, but also influence and shape the information discussed in the public debate by the frames that they apply in their reporting. Reese (2001) emphasises that studying the concept of framing is a useful approach, as it has the potential to get beneath the surface of news coverage and expose the hidden assumptions.

In the framing literature, both generic frames and issue-specific frames are studied. While generic frames are abstract and applicable to a wide range of topics, issue-specific frames are more concrete and usually exclusively identified in relation to a certain topic (Brugman et al., 2017). Scholars (e.g., Borah, 2011; Brugman et al., 2017) have advocated studying generic frames, as it allows for the identification of patterns and effects over time and across topics. Furthermore, comparing and generalizing results is much easier with generic frames than with issue-specific frames.

To date, there is no generic framework available for analysing and understanding the legitimation processes of technological innovations in the public discourse. Most of the media analyses in this domain are either quantitative studies focusing on prominence and sentiment (e.g., Binz et al., 2016; Markard et al., 2016) or qualitative case studies focusing on descriptions of events (e.g., Flipse & Osseweijer, 2012; Smink et al., 2015; Zschache et al., 2010). Both designs have their advantage and disadvantage. Quantitative studies indicate the prominence of an innovation in the public agenda, and provide the opportunity to compare technological innovations. However, these studies do not provide insights into the actual processes of gaining legitimacy in the public discourse. Qualitative media analyses provide insights into case-specific content written about an innovation, but make it difficult to compare different innovations. Furthermore, solely describing events and linking these to legitimacy might overlook important domains in which technological developments should be accepted. Therefore, our aim is to investigate whether the four pillars of legitimacy can serve as a framework for analysing the public discourse on science and technology and the structure of the dynamics of the legitimation processes.

3.2.2 Four pillars of legitimacy

In the institutional literature, several types of legitimacy are delineated. Suchman (1995) distinguished three types, cognitive, moral, and pragmatic legitimacy, all of which involve a generalised perception or assumption of legitimacy but rest on somewhat different behavioural dynamics. Ruef and Scott (1998) combined pragmatic and cognitive legitimacy, renamed moral as 'normative' legitimacy, and added the regulative component. Scott (2013) later continued with these three elements and defined them as 'pillars'. Other scholars combined Suchman and Ruef and Scott's distinctions into four pillars of legitimacy: cognitive, moral or normative, pragmatic, and regulative (e.g., Binz et al., 2016; Walker et al., 2014).

When aligned, the strength of the pillars' combined forces is at its highest. However, when the pillars are misaligned, they can cause confusion and conflict (Scott 2013). The four pillars of legitimacy do not constitute a hierarchy. In fact, within a time-frame, they often co-exist or overlap (Suchman 1995).

Cognitive legitimacy. Cognitive legitimacy involves the spread of knowledge regarding a technological innovation to social audiences (Aldrich & Fiol, 1994). Two variants of cognitive legitimacy can be identified, legitimacy based on comprehensibility and legitimacy based on taken-for-grandness (Suchman, 1995). In the case of technological innovations the former is about understanding the working principles of the innovation (Scott 2013). The latter arises when the innovation itself becomes an integral part of the dominant institutional framework in a particular social system (Kaganer et al., 2010). Taken-for-grandness can be viewed as the highest form of legitimacy, as it is implied that the innovation is embedded in the institutional system, and it is unthinkable to have a system without the innovation (Aldrich & Fiol, 1994). This form of cognitive legitimacy is rarely attainable in the early stages of innovation diffusion. In the context of GM food, the innovation is still widely contested and not yet integrated in the social system. Therefore, the focus in this study will be on the comprehensibility part of cognitive legitimacy: the degree to which a technology is known and understood.

Normative legitimacy. Normative legitimacy involves judgements about whether an innovation is right for society (Suchman, 1995). These judgements are based on norms and values that are socially constructed over time. According to Scott (2013, p. 64) values are 'conceptions of the preferred or desirable, together with the construction of standards to which existing structures or behaviours can be compared and assessed', while norms specify legitimate ways of how and which technologies should be developed. Ultimately, when normative legitimacy is achieved in its highest form, these judgements are perceived as objective and natural by the actors. The emphasis of the normative pillar is on promoting broad pro-social logics of justice and welfare (Suchman, 1995). In the context of GM food, opposing arguments are often infused with a highly emotional and moralizing rhetoric, with a focus on societal justice instead of individual gains (Hielscher et al., 2016). This rhetorical approach indicates a prominence of the normative pillar.

Pragmatic legitimacy. Pragmatic legitimacy rests on the self-interested calculations of the innovation's most immediate audiences (Suchman, 1995). It is about the utility that a technological innovation has for its stakeholders (Binz et al., 2016). This utility can be either of direct value to the stakeholder group or of more indirect value, being responsive to larger interests and goals (Suchman, 1995). Whereas normative legitimacy focuses on the utility for society, pragmatic legitimacy focuses on stakeholders' self-interest, 'what's in it for me' (Walker et al., 2014). Kaganer et al. (2010) argue that this type of legitimacy plays an important role in shaping the early stages of the diffusion of an innovation, as stakeholder groups will adopt an innovation only if they see a (potential) value in it. In the organizational context, Suchman (1995) argues that pragmatic legitimacy is the easiest form to manipulate for organizations, as it reflects direct exchange and relations of influence between a focal organization and its specific constituents. However, with regard to technological innovations, especially contested ones such as GM food, the field is much more diffuse as a larger and more diverse group of stakeholders are involved, and a clear agent is often lacking.

Regulative legitimacy. Regulative legitimacy is associated with the alignment of new practices with existing rules, laws, and regulations that are created by governments, credential associations, professional bodies, or powerful organizations (Zimmerman & Zeitz, 2002). Technologies that conform to existing rules, laws, and regulations, arguably possess a higher level of regulative legitimacy than technologies that are not in line with them (Binz et al., 2016). In the case of radical innovations, rules and regulations often do not exist, which makes (lobbying) activities that influence and shape policy-making especially relevant (Jansma et al., 2017). When GM food was in its early developmental phases, there was no clear regulatory framework. Only later was the policy set on a European level, and since then, it has been further extended and refined. Opponents and proponents of GM food have tried to shape and influence this regulatory process (Frewer et al., 2004).

3.3 Method

3.3.1 Design and instrument

By using the four pillars of legitimacy (cognitive, normative, pragmatic, and regulative) as a framework to study the media coverage of GM food, our aim was twofold. First, we wanted to investigate whether these pillars can be used as a framework for structuring the public discourse on technological innovations to gain insights into the legitimacy process as a whole. Second, we were interested in the dynamics of these pillars. For example, whether the pillar that is the most apparent is also the most contested one or the most agreed upon or whether specific arguments are used in a pillar either in favour of or against the innovation.. By analysing these dynamics, we aim to enhance our understanding of the process of technology legitimation: the actors and arguments involved in making an innovation legitimate or preventing it from becoming legitimate.

3.3.2 Corpus

The corpus for the media analysis consisted of all articles on GM food that were published in all Dutch national newspapers (N=9) between 1996 and 2016. Articles were collected using the LexisNexis Academic Database. The starting year, 1996, was chosen as this was the first time that newspapers explicitly started using the term 'genetisch gemodificeerd voedsel' (GM food in Dutch). The last year of coverage, 2016, was the last full year available in the database at the time of our analysis. In total, 372 articles, containing the term, were included in our corpus. This specific term is the most commonly used term in Dutch and was therefore most likely to produce an adequate sample of all articles on the topic. During the analysis, irrelevant articles (i.e., articles in which GM food was mentioned without any further information about it) were excluded from the sample, resulting in a total corpus of 287 articles.

3.3.3 Analysis

For the analysis a codebook was created that consisted of codes for identifying the article and the overall sentiment and codes for analysing the pillars of legitimacy, including the dynamics of these pillars (see Table 3.1). Identification elements, including date and year, and newspaper are relevant as they give insights in the timeline of the public discourse on GM food and the newspapers that reported about it. The unit of analysis of these codes was the whole article. Codes to identify the pillars of legitimacy and the dynamics of these pillars included the four pillars based, the sentiment in these pillars, arguments in favour or against GM food, and stakeholders. The pillars were based on the literature, and the unit of analysis was every text part in an article that could be linked to a specific pillar. In every coded pillar, arguments were coded based on statements that were either in favour of or against GM food. The arguments were derived from the 'Argumentenkaart genetisch gemodificeerde gewassen' (Arguments card for GMOs in Dutch) developed by the Ministry of Housing, Spatial Planning, and the Environment (Rijksoverheid, 2009).The stakeholders were inductively identified based on the media-articles.

The media articles were coded by one of the authors. To indicate measurement consistency (Tinsley & Weiss, 2000), intercoder reliability was based on ten percent of the corpus. One round of coding was conducted with a social science researcher who was not linked to this study, to prevent any biases. This resulted in substantial agreement on all codes (see Table 3.1).

Table 3.1 *Coding Scheme*

Code	Description	Unit of analysis	Cohen's Kappa
Date and year		Article	-
Newspaper		Article	-
Overall sentiment		Article	0.90
Positive	Mainly positive statements about GM food.		
Neutral	No preference in favour or against GM food.		
Negative	Mainly negative statements about GM food.		
Ambivalent	Both positive and negative statements about GM food.		
Pillars of legitimacy	Text parts that can be directly or indirectly linked to GM food	Pillar (sentences linked to a specific pillar)	0.67
Cognitive	Knowledge and information about GM food, including its description, explanation of its working principles and (scientific) studies about its (potential) effects.		
Normative	Moral judgements about GM food; whether it is 'right for society', including value judgements, norms and beliefs.		
Pragmatic	Utilitarian judgement on GM food, practical advantages and disadvantages for particular stakeholders.		
Regulative	Descriptions and judgements of rules and regulations on GM food by the government or other formal authorities.		

Table 3.1 *Continued.*

Code	Description	Unit of analysis	Cohen's Kappa
Sentiment of pillar		Pillar (sentences linked to a specific pillar)	0.66
Positive	Only positive statements about GM food.		
Neutral	No reference to positive nor negative statements.		
Negative	Only negative statements about GM food.		
Ambivalent	Both negative and positive statements about GM food.		
Arguments		Sentence	0.82
Ecology	Whether GM food is good or bad for the environment, including crops, biodiversity, and harvests.		
Economy	Whether GM food is good or bad for the economy, including gross national product, profits, and food prices.		
Ethics	Whether the use of GM food is right or wrong, including religion, prevention of famine, and food shortage.		
Public health	Whether GM food harms human health or not, including pesticides, allergic reactions, and (unknown) consequences of GM food.		
Stakeholders		Sentence	0.85
EU			
Dutch government			
EU governments (besides NL)			
US government			
NGOs			
Biotechnology companies			
Research institutes			
Farmers			
Companies			
Shareholders			
Investors			
General public			
Media			
Other			

3.4 Results

In this section the results of the media analysis are discussed. First, a holistic perspective on the development of the pillars over time will be given. Next, the dynamics of the pillars will be discussed in the order of the frequency of the pillars.

3.4.1 General overview

Several events and actions affected the GM food debate. When the events were described, it was mostly in a negative way (see Figure 3.1), and the normative pillar was mostly addressed, focusing on whether it is 'right' to implement GM food in the society or not (see Figure 3.2). News media focused less on the explanation and technical details of GM food (cognitive pillar), the potential benefits (pragmatic pillar), and the laws and the regulatory process (regulative pillar). In a media article, the cognitive pillar and the normative pillar often co-existed with each other, and with the pragmatic and regulative pillar (see Table 3.2). Articles addressing only one pillar often addressed the normative pillar, and hardly addressed the pragmatic pillar. This co-occurrence was not time-bound, but rather could be linked to the type of article (longer opinionated and background articles).

Table 3.2 *Frequency of the co-occurrence of pillars in an article*

	Cognitive	Normative	Pragmatic	Regulative
Cognitive	38*	85	40	35
Normative		93*	41	46
Pragmatic			5*	13
Regulative				13*

**Only this pillar was addressed in the media article.*

In the pillars, all four types (ecological, economic, ethical and public health) of arguments appeared, but the frequency and the types of arguments differed per pillar (see Figure 3.3). In the cognitive and pragmatic pillars, there were relatively many arguments present, in comparison with the normative and regulative pillars.

Among the stakeholders, the general public, NGOs, and the EU government were mentioned the most (see Figure 3.4). Other stakeholders that were often mentioned were research institutes, private companies (other than biotech companies), biotech companies, and the Dutch government. Several other stakeholders that were coded (the US government, media, investors, shareholders) were less addressed by the media.

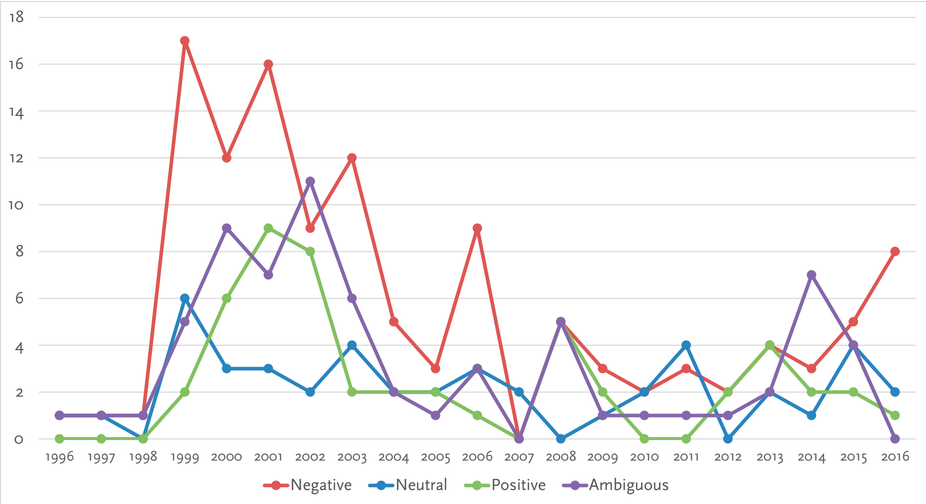


Figure 3.1 *Sentiment towards GM food*

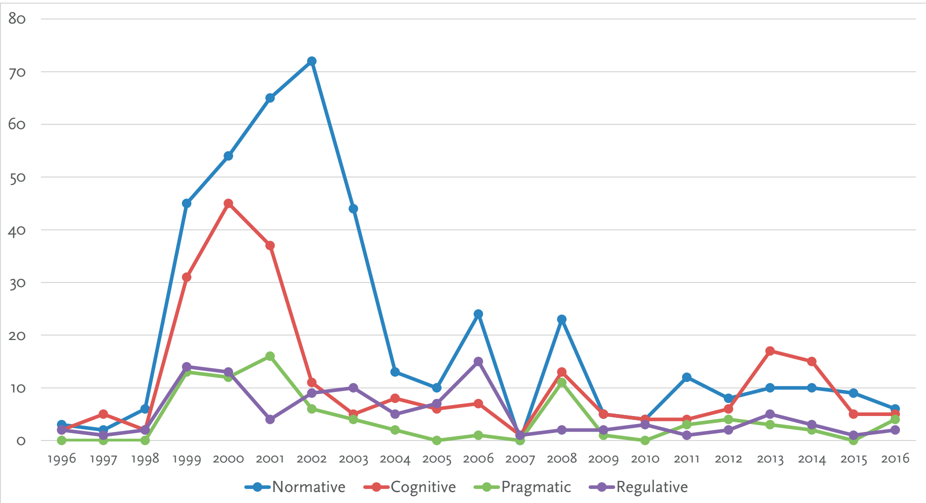


Figure 3.2 *Frequency of the pillars of legitimacy*

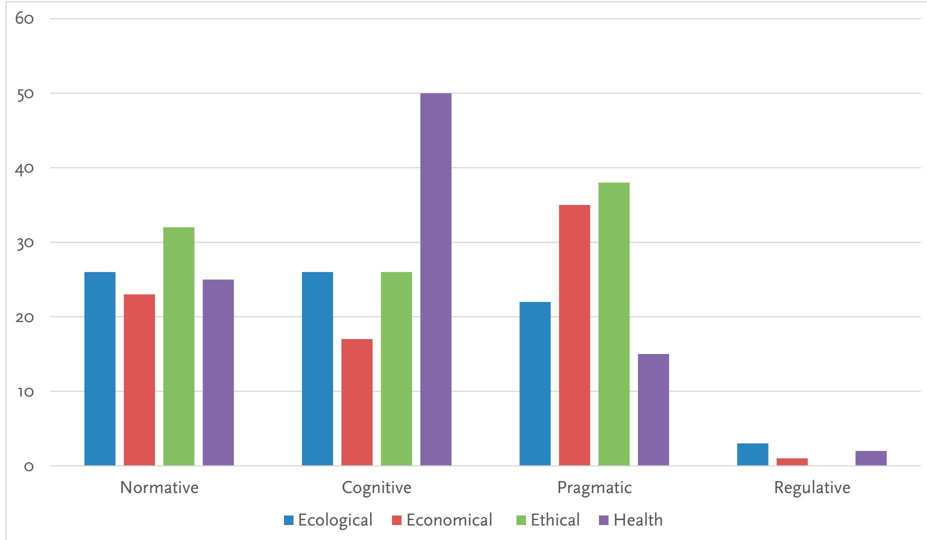


Figure 3.3 *Pillars of legitimacy and arguments*

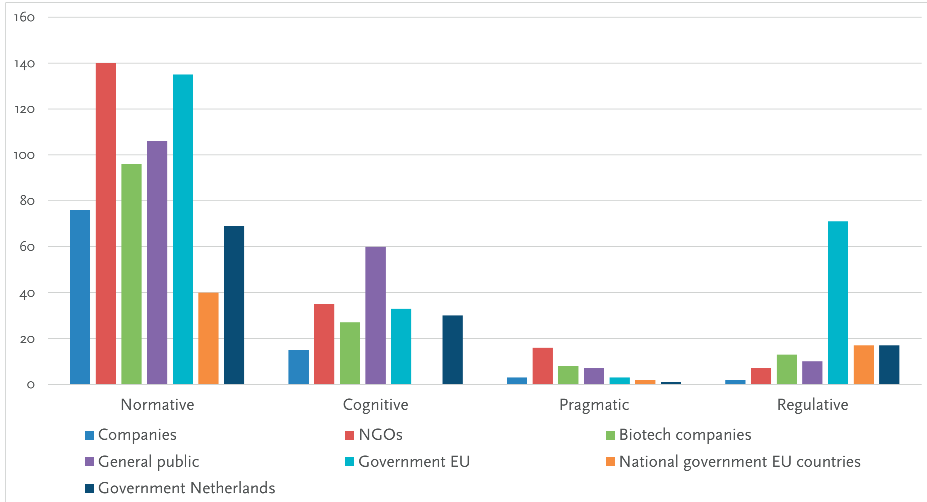


Figure 3.4 *Pillars of legitimacy and stakeholders*

3.4.2 Normative legitimacy

Over the years, the normative pillar has been most often addressed by the news media (see Figure 3.2). A number of events dominated this pillar. These events were described from a perspective that focused on the question of whether GM food is right for society or not. In this pillar, the public discourse was predominantly negative (see Figure 3.1). Although relatively few explicit arguments were mentioned by the media in this pillar, all four areas of argumentation were present.

In the period from 1996 to 2003, the public discourse was affected by multiple campaigns that were set up to emphasise that GM food was 'not right', using the arguments that GM food is against the values and norms of society and that it is harmful for the environment or human health, or not using any specific arguments. During these campaigns, GM crop fields were destroyed, protests increased, and activists attacked companies for using genetically modified ingredients in their products. Biotech companies were highly criticized in the media. In addition, the Dutch media reported on the British debate on GM food. Following the British media, in 2001 the Dutch media introduced the term 'Frankenstein food' into the public debate as a reference to GM food. In the same period, the media reported on developments in GM food in the US. Already in the 1990s the US was much more open to implementing GM food and allowed the growing of GM crops. The Dutch media reported about these developments mostly in a negative way.

Following the debate in the public sphere, a normative debate started to arise in the political sphere as well. This debate was mainly at the European level, and was centred around the moratorium and regulations on food labelling. The media mainly addressed proponents of both policies, who emphasised that establishing appropriate measures was the right thing to do for European citizens. They used arguments in favour of these measures based on health risks that were not clear yet and from an ethical point of view, including the view that human beings should not mess with nature, or they did not use any argumentation.

3.4.3 Cognitive legitimacy

Knowledge and understanding of GM food, and thus the cognitive pillar, are seen as a crucial factors for gaining legitimacy. However, the cognitive pillar was far less addressed in the public discourse than the normative pillar (see Figure 3.2). Overall, the sentiment was negative but it was much more balanced with ambivalence (both positive and negative accounts) and positivity than the normative pillar (see Figure 3.1). Although the cognitive pillar was less addressed by the news media than the normative pillar, more arguments were linked to it.

The majority of articles in this pillar were about knowledge of the effectiveness and risks of GM food, and less about its working principles. Throughout the years, the public was informed by the media about conflicting scientific studies and research reports by various stakeholders (e.g., NGOs and governments) on the risks of GM food, mostly regarding health and the environment. From the end of 2013 onwards, the media reported mostly positive about views of GM food in regard to human health.

Another issue that appeared in this pillar was the lack of knowledge regarding GM food among the general public and politicians. In several articles it was reported that the general public was not informed enough, despite a national debate 'Eten en genen' (Food and Genes), which was organized by the Dutch government. Additionally, various studies were conducted to analyse the knowledge of citizens regarding GM food. These studies showed that most citizens were aware of the existence of GM food, but not about its working principles.

3.4.4 Pragmatic legitimacy

The pragmatic pillar, encompassing paragraphs that were written from the perspective of the utility for specific stakeholder groups, was little addressed (see Figure 3.2). In contrast to the other pillars of legitimation, the pragmatic pillar was addressed mostly in positive way (see Figure 3.1). Despite the unknown risks and normative accounts, there seemed to be an agreement in the public discourse on the potential usefulness of GM food for particular groups.

In the pragmatic pillar two main utilities of GM food for two different types of stakeholders were addressed. One utility was the reduction of pesticides and herbicides, which could be very helpful for farmers. The other utility was the possibility of growing GM food in areas where crops cannot usually be grown, mostly dry areas in developing countries. From an economic and ecological point of view, biotechnology companies stressed the utility for farmers, as GM food could reduce the use of pesticides and herbicides and ensure more effective weed control, leading to security and therefore an increase in harvests, and less damaging effects on the environment.

In 2001 the United Nations Development Program (UNDP) issued a report that stated that although the dangers should not be overlooked, food safety should not dominate the road to food security. Articles that appeared during this period addressed topics related to whether GM food can solve the food problem for developing countries, and therefore play a substantial role in poverty reduction. Again, in the period around 2008, there was a slight increase in attention, as it was emphasised again that GM food could be a solution for developing countries.

3.4.5 Regulative legitimacy

Although many regulations and directives with regard to GM food were created, the regulative pillar was rarely addressed in the media (see Figure 3.2). When writing about the regulatory process, the media mostly reported on it in a negative way (see Figure 3.1).

Whenever regulations and directives were discussed, the discussion often concerned the end of the existing moratorium in the EU (which was in place from 1998 to 2003), the introduction of rules concerning labelling, and restrictions on the release of GMOs into the environment. Most of these regulations were discussed at the European level. The restriction on the admission of GM food within the European borders resulted in an official complaint by the United States, Canada, and Argentina at the WTO. These complaints led to the conclusion that the EU wrongly withheld GM food from its borders between 1998 and 2003. With regard to the restrictions on the conscious release of GMOs, media reported on how member states were deemed to transpose European legislation into national legislation, and how this transposition resulted in a warning for 12 of the EU's member states, including the Netherlands, Germany, and France, for not having done that in time. Regulations concerning the labelling of GM food were even more disputed.

3.5 Discussion and conclusion

3.5.1 Discussion

Legitimacy is important for both the diffusion and acceptance of technological innovations. In this study the four pillars of legitimacy, the normative, cognitive, pragmatic, and the regulative pillar, show to be a promising framework for studying legitimacy in the public discourse. The content of the media coverage on GM food could easily be linked to one of the four pillars. The dynamics of the pillars differed in terms of the sentiment, the arguments and the stakeholders mentioned. In the debate on GM food, the focus was mainly on the normative side, and mainly negative. The cognitive pillar was also addressed in a negative way, but to a lesser extent; and the regulative and pragmatic pillars were hardly addressed by the media. Whereby the pragmatic pillar was mostly mentioned in a positive way. In line with Suchman (1995), multiple pillars co-occurred per news article. The pragmatic and regulative pillar were hardly addressed on their own, nor in combination with each other.

Taking a look at the dynamics of the pillars, we gained interesting insights in the legitimation process. First, we found that in the normative pillar relatively few arguments were present. This implies that emotional and irrational factors dominated this pillar, which is in line with various studies that indicate that opponents of GM food tend to address it by focusing on an emotional rhetoric. Among these opponents NGOs are seen as the most active actors (e.g., Harvey, 2007; Legge & Durant, 2010). In our study, NGOs were indeed the stakeholder group that was most often mentioned in the normative pillar. Furthermore, the public debate was mostly dominated by a negative sentiment in this pillar, highlighting that GM food is a contested innovation in the public domain.

Second, after the normative pillar, the cognitive pillar was most often addressed by the media. However, in this pillar little knowledge dissemination took place regarding explanations of the working principles of GM food. Instead, the public was confronted with contradictory results from scientific studies on the risks and benefits of GM food. In the context of radical technological innovations that have a major impact on society, such as GM food, it is extremely complex to come to an objective risk assessment. Scholars have argued that there is no such thing as a 'sound science' of sterile risk assessments or neutral scientific claims (Kearnes et al., 2006; Legge & Durant, 2010). New technologies often operate in the context of wider public concerns in which the public debate is multidisciplinary in nature and has competing scientific values (Legge & Durant, 2010). The lack of explanations of GM food in the cognitive pillar clarify earlier findings of Hanssen et al. (2015) and Lucht (2015) who noted that there seems to be a lack of knowledge among the general Dutch public regarding GM food.

Third, both the regulative and pragmatic pillars were hardly addressed. The pragmatic pillar was the only pillar that was addressed positively more often than negatively. This finding is in accordance with Lucht (2015), who emphasised that adopters are often characterized by pragmatic positions towards GM technologies. The positive characteristics of GM food attributed from a pragmatic point of view might indicate that this pillar offers the most potential for legitimacy. However, as Scott (2013) emphasised, it does not suffice to create legitimacy in only one pillar, because confusion and conflict could result.

In all pillars, different types of arguments appeared. However, the perspectives from which the arguments were described, and therefore the pillar, differed. For example, an economic argument in the pragmatic pillar was about the higher income that could be gained with GM food for farmers. In the normative pillar economic arguments focused on whether it is right or wrong to implement GM food based on the argument that it might benefit the society economically. Similar differences were found in the ecological, ethical and health arguments. This finding shows that it does not suffice to evaluate legitimacy based on an analysis of arguments or events as has been done in most qualitative media analyses of innovations.

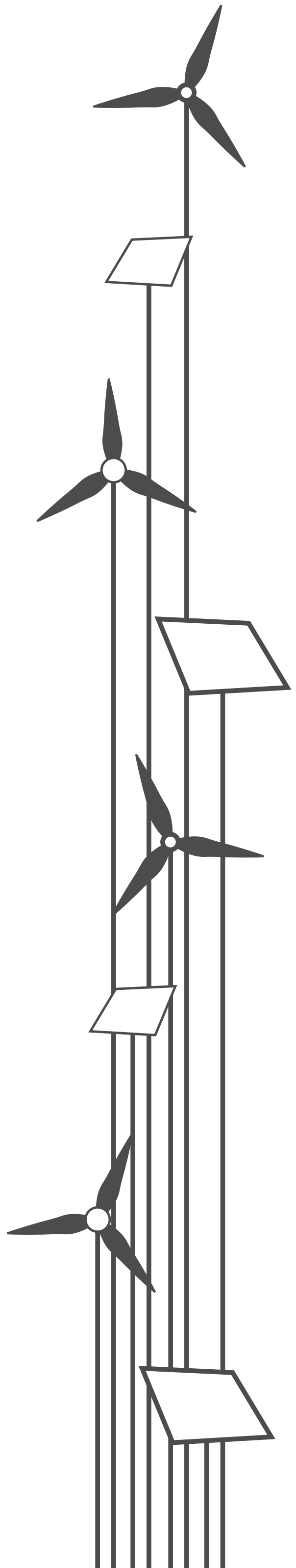
3.5.2 Limitations and suggestions for future research

Some limitations of this study should be acknowledged. First, while this study shows the usefulness and great potential of the four pillars of legitimacy as a framework for studying public discourse, other innovations should be studied as well to obtain further proof. As GM food is a contested innovation, a substantial number of articles in the media could be found reporting on it. It would also be interesting to analyse an innovation that is less contested and determine whether all pillars are still reflected or not. Additionally, it would be interesting to apply this framework to innovations that differ in their technical features and social-political context.

Second, we studied the public discourse to analyse legitimation processes in the public domain. Various studies (e.g., Harvey, 2007; Legge & Durant, 2010; Tosun & Schaub, 2017; Twardowski & Malyska, 2012) have pointed out that in the case of GM food the media are more influenced by opponents than proponents of GM food. Although the media reflect the public discourse, this reflection cannot be linked one-on-one to the public attitude. Nevertheless, the public discourse as portrayed by the media is important for creating the legitimacy of technological innovations (Bergek, Jacobsson, & Sandén, 2008).

3.5.3 Conclusion

Within innovation literature, legitimation is regarded as an important function of the development and implementation of technological innovations. The public sphere is one of the most important domains in which this legitimation occurs, which is both reflected and influenced by the public discourse. This study shows that the four pillars of legitimacy can be applied as a generic framework to study technological innovations in the public discourse. The framework gives us insights into the state of the pillars of legitimacy of an innovation. From a theoretical point of view it enhances our understanding of the legitimacy and legitimation processes of different technological innovations, and it is an instrument for comparing the legitimacy of different technological innovations. From a practical point of view, it provides insights in the areas that need further attention when communicating about an innovation in the public sphere.



4

Kissing natural gas goodbye? Homeowner versus tenant perceptions of the transition towards sustainable heat in the Netherlands

Jansma, S. R., Gosselt, J. F., de Jong, M. D. T. (2020). Kissing natural gas goodbye? Homeowner versus tenant perceptions of the transition towards sustainable heat in the Netherlands. *Energy Research & Social Science, 69*, 101694-101704.

4.1 Introduction

Following the Paris Agreement, various governments have set ambitious targets for replacing their fossil-based energy system with a system based on renewable energy. Governments differ, however, in their choices and pathways to achieve these aims. In the Netherlands, the national government has started down the path towards sustainable heat to drastically reduce CO_2 emissions. With the same policy, the government aims to combat seismic activities caused by gas extraction in Groningen, one of the northern provinces. By 2050 the country should be natural gas free. This is a major challenge: Because of the country's own natural gas reserves the Dutch energy system has an exceptionally high share of natural gas. This has led to a lock-in of the residential sector with almost 90% of all households being connected to the natural gas grid (Eurostat, 2018; Miedema et al., 2018). Residential buildings cause approximately 9% of the country's CO_2 emissions, with two-thirds of the energy consumption being spent on heating (Schoots et al., 2016).

A transition towards sustainable heat can thus have a substantial impact on the CO_2 emissions. However, cutting off every household from natural gas is a major technical and social challenge, as it requires citizens to adopt alternative heating systems and invest in the insulation of their houses (Mills & Schleich, 2012). The national government has stated that the transition will be gradually executed by local governments, with an average of 50.000 households per year. To accelerate the transition, the government allocated subsidies of at least four million euros in 2018 to 27 municipalities to disconnect specific neighbourhoods from the gas grid. However, local governments are struggling with getting citizens on board for the transition (Scholte et al., 2020). The allocated subsidies only cover part of the costs and local governments do not have any legal means to force households to disconnect from the gas grid. Additionally, compared to other European countries, Dutch households appear to be less interested in energy-related home renovations, due to concerns about the investment costs (Backhaus, 2019).

This study aims to explore and to compare the perceptions of homeowners and tenants —living in a subsidized and unsubsidized neighbourhood— of the transition towards sustainable heat, to get more insights in how to get them on board. In this introduction, first the difference between homeowners and tenants in the transition will be described (Section 4.1.1), followed by a discussion of the influence of the local context (Section 4.1.2) and other factors that might influence the perception of sustainable heat (Section 4.1.3). The introduction will end with an overview of our research (Section 4.1.4).

4.1.1 Homeowners and tenants

The challenge for local governments is to create acceptance for and engage residents in the transition towards sustainable heat. However, there is no such thing as homogenous acceptance. Various stakeholders may have different views on the transition (Scherhaufer et al., 2017; Van Middelkoop et al., 2017). In particular, a distinction can be made between homeowners and tenants. Homeowners need to take action and invest in the transition themselves, while tenants depend on their housing corporation or landlord/lady. Although tenants have little responsibility for implementing energy-efficient measures in their homes, they are still an important stakeholder group to consider as housing corporations and landlords need the approval of 70% of their tenants when renovating residential buildings (Rijksoverheid, 2008). Van Middelkoop et al. (2017) found that Dutch tenants have strong feelings of autonomy regarding their homes and do not want to be forced by the government to make them more sustainable.

In the Netherlands, 60% of the households consist of homeowners, 30% consist of tenants renting from a housing corporation, and 10% consist of tenants renting from a private landlord/lady (Sociaal en Cultureel Planbureau, 2018). It may be expected that the differences in responsibility affect people's attitudes and interests in the energy transition, leading to the question of whether each group needs different approaches to the process regarding communication and engagement. However, little research has been conducted on this topic. Our research question is: To what extent do homeowners and tenants differ in their perceptions of a transition towards sustainable heat?

4.1.2 Local context

As the transition towards sustainable heat is implemented in specific neighbourhoods, community acceptance and engagement are important for its success. Citizens can influence the transition through their support of or resistance to changes in the heating system and can even decide to become producers of renewable energy themselves through the installation of PV-panels or by participating in a community energy initiative (Van der Schoor et al., 2015). With regard to the energy transition, Sagebiel et al. (2014) found that transparency, the sharing of renewable energy, and democratic control are important aspects that citizens consider before engaging in the transition. However, the local context in which citizens operate is important for their behaviour. Contextual factors identified as drivers for the energy transition include guidance from regional and local governments through expertise and financial support (Van der Waal et al., 2020), cohesion and trust in other community members, and highly committed community members who actively engage in the transition (e.g., a civil neighbourhood council) (Van der Schoor & Scholtens, 2015).

The national subsidies some municipalities received for the transition towards sustainable heat are a contextual factor that might affect the transition in neighbourhoods. They not only provide financial incentives, but also raise expectations, clarify responsibilities, promote professional input, and facilitate the process in terms of planning and communication. The municipalities that received a subsidy had to develop and commit to a timeframe for the transition in the chosen neighbourhood and start the transition within a year after the subsidy was granted (Rijksoverheid, 2018). While earlier research showed that that contextual factors influence community acceptance and engagement in the energy transition, no specific connections were made to the transition towards sustainable heat or the distinction between homeowners and tenants. Therefore, our second research question is: To what extent does local context—specifically the distinction between a subsidized and a nonsubsidized neighbourhood—affect homeowners' and tenants' perceptions of the transition towards sustainable heat?

4.1.3 Other factors influencing the perception of the transition towards sustainable heat

Next to the distinction made between homeowners and tenants and the local context, there are other factors that may influence the perception of the transition towards sustainable heat as well. In earlier (quantitative and qualitative) studies, various factors influencing residents' attitudes, intentions, and behaviours were found (e.g., Ástmarsson et al., 2013; Broers et al., 2019; Ebrahimigharehbaghi et al., 2019; Miedema et al., 2018; Nair et al., 2010; Risholt & Berker, 2013; Van Middelkoop et al., 2017; Visscher et al., 2016; Wilson et al., 2015), which can be divided into five categories: financial aspects, knowledge and information, process related factors, environmental concerns, and socio-demographic characteristics. Most of the earlier studies focused solely on homeowners and concentrated on renovation measures instead of including both homeowners and tenants and investigating the sustainable transition as a whole. Nevertheless, they provide relevant insights for this study.

The first factor involves the financial aspects of the transition. The few studies that have compared the perceptions and motives of homeowners and tenants regarding energy-efficient measures have predominantly focused on this factor. For homeowners, financial concerns involve the question of whether their investments would pay off through a decrease in energy use and an increase in the value of their house (Broers et al., 2019; Wilson et al., 2015). Homeowners who perceived energy-efficient measures as a good investment and/or received a government loan or subsidy were more inclined to adopt these measures, while a lack of money and an aversion to delayed gain prevented investing in energy-efficient measures (Broers et al., 2019; Wilson et al., 2015). Tenants' concerns involved the question whether the decrease in energy use would cover the higher rent (Ástmarsson et al., 2013; Visscher et al, 2016). Mixed results were found when comparing the importance of financial aspects for homeowners and tenants. Franke and Nadler (2019) found that financial motives for energy efficiency were more important for homeowners than for tenants, as purchase decisions are more long-term oriented and cost-intensive than are rental decisions. Other researchers concluded that financial motives were equally important for homeowners and tenants (Backhaus, 2019; Cajias et al., 2019; Visscher et al., 2016).

A second factor is knowledge and information. This includes technical knowledge—the steps that need to be taken to make the home more energy efficient—and policy knowledge—the regulations and possible financial instruments (Nair et al., 2010; Risholt & Berker, 2013). Broers et al. (2019) found that homeowners who have technical knowledge, who feel that they can gain access to objective information, and/or who heard about positive experiences from their network, are more inclined to adopt energy-efficiency measures. In contrast, Ebrahimigharehbaghi et al. (2019) and Wilson et al. (2015) identified a perceived lack of credible information as an important barrier for homeowners to adopt sustainable measures. The knowledge component might be especially relevant for homeowners, who need to arrange and implement sustainable measures themselves, while tenants must rely on their housing corporation or landlord/lady.

A third factor involves the process of the transition, including policy-making, the complexity of the process, and trust in responsible agents. In their system analysis of drivers and barriers to a transition towards biomass gasification as an alternative for natural gas, Miedema et al. (2018) found a lack of mandatory policy agreements to be one of the biggest obstacles for the transition for both the private and rental sectors. Additionally, Van Middelkoop et al. (2017) found that homeowners and tenants, despite their strongly felt autonomy for their houses, supported government policies on energy performance improvements to existing homes. However, both studies were conducted before the Dutch policy about disconnecting every household from the gas grid was issued, and it remains to be seen whether homeowners and tenants are still in favour of government policies towards sustainable heat. The complexity of the process was also identified as a barrier. Ebrahimigharehbaghi et al. (2019) and Wilson et al. (2015) found that complexities related to carrying out energy measures, the cognitive burden (or transaction costs) of making complex and irreversible investment decisions, and the foreseen 'hassle factor' of having one's daily life disrupted by renovations are relevant barriers for homeowners. Governments or other actors could guide the transition by organizing the installation of energy-efficient measures and preselecting relevant sustainable alternatives in combination with financing options, or using project managers to guide the entire process for homeowners (Broers et al., 2019; Risholt & Berker, 2013). However, research on the acceptance of local energy projects showed that such actions can only be effective when the responsible agents are trusted (Bronfman et al., 2012; Liu et al., 2019; Shaw et al., 2015). For homeowners, the most obvious responsible agent is the local government, responsible for the vision and the plan for the transition in their neighbourhood; for tenants, the most obvious responsible agent are housing corporations or landlords/ladies, in charge of insulating homes and implementing new heating systems.

A fourth factor involves environmental concerns—i.e., the extent to which people feel responsible for the environment and are willing to take actions. Both Broers et al. (2019) and Ebrahimigharehbaghi et al. (2019) found that environmental concerns play an important role in triggering interest in energy-efficient measures. They concluded that this factor is especially relevant in the early stage, as it correlates with awareness about the transition and motivation to search for information. Similarly, Koirala et al. (2018) found environmental concerns to be one of the predictors of citizens' willingness to participate in local energy initiatives.

The fifth factor involves citizens' background variables. It seems to be easier for highly educated people to acquire the relevant knowledge and skills for the transition (Broers et al., 2019; Ebrahimigharehbaghi et al., 2019). Furthermore, a negative correlation was found between age and the adoption of measures, since older people might feel less certain whether their investment will pay off during their remaining time living in their homes (Kastner & Stern, 2015). These studies focused on homeowners; whether such relations exist for tenants as well is thus far unknown.

4.1.4 This study

To compare homeowner and tenant perceptions of the transition towards sustainable heat and to study the influence of the local context, we conducted a mixed-method study including homeowners and tenants from two different neighbourhoods. First, we conducted a series of focus groups to explore relevant issues about the transition towards sustainable heat in perceptions of homeowners and tenants to obtain. We used focus groups, because the interaction of the participants might reveal new viewpoints and provide insights into their underlying knowledge and motives (Morgan, 1994). Second, we conducted a survey, based on insights from the focus groups and from the literature. The aims of the survey were: (1) to compare the perceptions homeowners and tenants have on relevant aspects of the transition towards sustainable heat, (2) to compare the antecedents of both groups' attitudes towards becoming natural gas free, and (3) to study the influence of the local context.

Two neighbourhoods from two different neighbouring municipalities in the East of the Netherlands were selected. Both neighbourhoods were designated by their municipality as a pilot case in the transition. The neighbourhoods had comparable characteristics, including a similar proportion of homeowners and tenants (mostly renting from housing corporations) and diverse types of homes (apartment-buildings, bungalows, terraced houses), with a majority of them being poorly insulated. Furthermore, both neighbourhoods had inhabitants with a wide variety in socio-economic status and from different age groups. An important difference between the neighbourhoods was that, just before our study started, one municipality received a subsidy of more than 4 million euros for accelerating the transition in the neighbourhood involved by supporting the disconnection of at least 500 houses from the gas grid, while the other did not. When receiving the subsidy, the municipality of the subsidized neighbourhood had to draw up a timeframe and start within a year; for the unsubsidized neighbourhood, there was no time frame. Furthermore, in the subsidized neighbourhood, a campaign for raising awareness about becoming natural gas free was launched, and several newsletters were sent to all households; in the unsubsidized neighbourhood only one newsletter was sent to every household.

4.2 Study 1 – Focus groups

4.2.1 Method

4.2.1.1 Design and instrument

Separate focus groups with homeowners and tenants were conducted. All the focus groups were based on the same guideline and addressed four themes: (1) the transition towards sustainable heat in general, (2) alternatives for natural gas, (3) the actors involved in the transition, and (4) the implementation process.

In a short introductory round, the participants were asked to explain why they liked or disliked living in their neighbourhood. After that, a short video was shown explaining the basics of the Dutch policy towards sustainable heat. The participants were then asked to discuss their opinions and feelings about this policy. Then, they saw a video explaining the three most viable alternatives for natural gas (electrical heat pump, biomass, and district heating). Again, the participants were asked to discuss these issues. After that, the participants were asked to write down and subsequently discuss the actors they thought are or should be involved in the transition. Finally, the participants discussed what they thought an ideal process of the transition towards sustainable heat would look like.

4.2.1.2 Participants and analysis

Four focus groups were conducted, two in each neighbourhood with homeowners and tenants being included separately. The focus groups were held in the neighbourhoods' community centres and were led by the first two authors. Participants were recruited with the help of civil neighbourhood councils (which organize social activities and represent citizens in local policies) and housing corporations. They were told that the focus groups would be about their opinions on plans for the transition towards sustainable heat in their neighbourhood. Every session consisted of six participants, with a total of 24 (12 in each neighbourhood; 12 tenants and 12 homeowners), all of whom were at least 18 years old (see Table 4.1).

The sessions lasted between 1.5 and 2 hours, and were audio recorded and transcribed for analysis. The transcripts were coded by the first two authors using thematic analysis, following the four main themes of the focus group guideline. During the coding process, the first theme (the transition in general) was divided into two subthemes (knowledge about and attitude towards the transition), and the other themes remained the same.

Table 4.1 *Participants in the focus groups*

	Homeowners Subsidized	Homeowners Unsubsidized	Tenants Subsidized	Tenants Unsubsidized
Homeowners vs. tenants				
Housing corporation	-	-	6	6
Private landlord-lady	-	-	-	-
Homeowner	6	6	-	-
Gender				
Male	3	4	4	2
Female	3	2	2	4
Energy label				
Low	4	6	5	6
Middle	1	-	1	-
High	1	-	-	-

4.2.2 Results

During the analysis of the transcripts it became clear that the homeowners and tenants in both neighbourhoods addressed similar issues and had similar concerns.

4.2.2.1 Knowledge about the transition

Both homeowners and tenants in both neighbourhoods emphasised that they had little knowledge about the national policy of the transition towards sustainable heat and even less about the plans for their neighbourhood. They had all heard in the news media about the intention of the national government to cut off every household from natural gas by 2050, but had no idea what this would mean for their neighbourhood or themselves. One participant, for example, stated, *"We all read in the newspaper that we're at the start of an immense transition, but nowhere it is explained what exactly will happen"* (homeowner, unsubsidized neighbourhood). Some participants had an idea of the implications of and difficulties related to making the infrastructure suitable for alternatives of natural gas. They mostly referred to adjustments needed in the electricity net of their houses and difficulties with insulating their houses, both of which were often mentioned in relation to costs. An illustrative comment was: *"It will cost thousands of euros to insulate my house in such a way that it will be suitable for an alternative to natural gas. I have a house that was built in the 1930s, which is always draughty. Who will pay for this insulation?"* (homeowner, unsubsidized neighbourhood). Most participants did not think they had much knowledge about possible alternatives for natural gas. They had heard about technical solutions such as district heating, electrical heat pumps, biomass, geothermic heat, heat from hydrogen, and nuclear energy through news media and via word-of-mouth. However, most did not have an idea about the working principles or effects of these alternatives. Only for district heating, which has existed in the Netherlands for a long time, did most of the participants have some ideas o—mostly negative, as they remembered stories of malfunctioning.

4.2.2.2 Attitudes towards the transition

When the participants were asked how they felt about the idea of being cut off from natural gas, most homeowners and tenants in both neighbourhoods responded negatively. The costs and feasibility were most often mentioned as concerns. Homeowners emphasised the installation costs of alternatives for natural gas, including insulating their homes and adjustments in the heating infrastructure. Tenants were afraid of an increase in their monthly rent due to the construction needed in their homes. One tenant explained, *"I already asked for adjustments in my house to increase the insulation. The housing corporation told me it would cost me 80 euros extra per month, which I simply cannot afford"* (tenant, unsubsidized neighbourhood). Furthermore, several participants referred to the magnitude of the policy, doubting whether it would truly be possible to cut off every household from natural gas. Nevertheless, most participants also saw benefits for the environment. They agreed it was important to decrease CO_2 emissions for future generations. One participant stated, *"Something needs to happen to keep the earth liveable for our children"* (tenant, subsidized neighbourhood). Other benefits mentioned, albeit less frequently than the environmental argument, were that the transition would decrease seismic activities in Groningen and that it would make the Netherlands less vulnerable, as the Dutch dependence on importing natural gas from other countries (such as Russia) would decrease.

4.2.2.3 Alternatives for natural gas

Almost all participants had a preference for natural gas and raised concerns when talking about alternatives, including sustainability, effects on comfort, long-term viability, and installation and utilization costs. Regarding sustainability, they doubted whether the heat used for district heating, which is often derived from waste processing or industry, is really sustainable. The same issue was raised when talking about biomass. Another concern involved their comfort of living, which could be negatively influenced by the alternatives. Some participants expected that an electrical heat pump would cause noise and occupy much space in their homes. Some also feared that it would be difficult to reach a comfortable temperature in cold winters with district heating or electrical heat pumps. Furthermore, participants expected that manure combustion for biomass energy could lead to odour nuisance. When talking about long-term viability, participants doubted whether it would make sense to change the entire infrastructure of gas pipes for a new alternative, as in the future, other alternatives (such as hydrogen power) might be suitable for distribution through gas pipes. They also doubted whether there would be enough heat to provide district heating to all households or enough biomass to burn. Installation costs and utilization costs were not only mentioned when talking about the transition in general, but also in relation to the alternatives. In particular, the electrical heat pump was considered to be an expensive alternative. The participants emphasised that for all alternatives to be effective, houses should be insulated, which would cost large amounts of money. Finally, participants talked about communal versus individual alternatives. District heating is clearly a communal alternative, while electrical heat pumps are an individual alternative. Most tenants had a preference for a communal alternative, while homeowners did not have a clear preference.

4.2.2.4 Actors involved in the transition

When the participants talked about actors they thought were involved in the transition, they often immediately discussed whether they trusted them or not. The local government was most often mentioned as the main responsible actor for the implementation of the transition in the neighbourhoods. However, especially in the subsidized neighbourhood, both homeowners and tenants doubted whether the local government had the intentions and capacity to steer the transition in the right direction. One participant said, *"The local government is responsible for the whole transition (...) I am especially concerned about the lack of expertise in the local council regarding this topic"* (homeowner, subsidized neighbourhood). In the unsubsidized neighbourhood, the participants also saw the local government as the main actor, but were less negative about it.

Another actor often mentioned by homeowners and tenants were housing corporations. Tenants thought housing corporations were responsible for the necessary adjustments in their homes. One participant stated: *"I am a tenant, if the housing corporation wants to change the house I am living in, they are responsible for it"* (tenant, subsidized neighbourhood). Although the tenants had some complaints regarding the sustainability measures implemented so far by their housing corporations, they did not doubt the intentions of this actor in the transition. Homeowners saw housing corporations as an important actor as well, as they thought housing corporations had major influence in the decision-making process within their neighbourhood. One participant said, *"I think that a housing corporation, which has much more houses in the neighbourhood than me as a homeowner, has an important say in the process"* (homeowner, unsubsidized neighbourhood). Some participants were sceptical about this role, while others thought it was good to have some major players at the table. Other actors mentioned by both homeowners and tenants, but to a far lesser extent and in a neutral way, were the civil neighbourhood councils, energy companies, and the net distributor.

4.2.2.5 Implementation process

All the participants found it important to be informed about the process of the transition. They emphasised that they want to be engaged in the early stages of the process, before pivotal decisions have been made. One participant said: *"I think it is important that they [the municipality] keep us informed about the different steps that are being taken in the process, and not just communicate about some moments of decision making in which we as residents can give our opinion without having any knowledge about the whole process."* (homeowner, subsidized neighbourhood). Not all participants wanted to be actively engaged in the process though. Some preferred a more passive form of engagement, thinking it would suffice to be informed about the overall process and important developments. However, homeowners and tenants in both neighbourhoods argued that the option of active engagement should be offered for a variety of themes, including the planning, the financial aspects, the choice of an alternative of gas, technicalities, and communication.

4.2.2.6 Conclusion

The themes that were discussed during the focus groups overlap with the determinants of the acceptance for the transition towards sustainable heat that have been found in the literature (see section 1.3) but also provide additional insights. Financial considerations, environmental concerns, the role of trust in prominent actors, knowledge about alternative technologies and the transition process, and participation options also emerged from previous studies as important factors in the transition towards sustainable heat.

In addition to the literature, the focus groups drew attention to concerns regarding the characteristics of the potential alternatives of natural gas. Although both homeowners and tenants recognized the importance to combat climate change, they had doubts about the sustainability of some alternatives of natural gas and, related to this, the long-term viability of alternatives. Another concern mentioned by both groups related to the influence of a different heating system on their comfort of living (e.g., the noise from electrical heat pumps). Furthermore, homeowners and tenants discussed the pros and cons of adopting and implementing a communal versus individual alternative.

4.3 Study 2 – Survey

4.3.1 Design and instrument

The questionnaire was constructed based on the results of the focus groups and the literature and consisted of five constructs: (1) knowledge about the transition (5 items), (2) environmental concerns (3 items), (3) attitude towards the Netherlands becoming natural gas free (2 items), (4) attitude towards the neighbourhood becoming natural gas free (2 items), and (5) preferred engagement in the transition (4 items). Furthermore, several single-item questions were asked about trust in different actors involved in the transition (municipalities, civil neighbourhood councils, housing corporations, energy companies, and net distributors), areas of interest (financial aspects, technical aspects, choice of alternative solutions, planning, and communication), and the importance of characteristics of alternatives for natural gas (installation costs, utilization costs, communality, comfort of living, sustainability, and long-term feasibility). These items were approached as single item questions as we were interested in trust in all specific actors and interest in all specific areas, and not in general levels of trust or interest. All the questions were asked using five-point Likert scales (see Table 4.2). The questionnaire took between 10 to 15 minutes to fill out.

As the questionnaire was not based on existing scales, we first tested the validity of the constructs by conducting a principal-component factor analysis (with varimax rotation) using all items measured for the five constructs. This led to a distinction between policy knowledge and technical knowledge. Furthermore, the attitude towards becoming natural gas free could not be divided in national and local level, but was combined into one construct. Environmental concerns and engagement remained as constructs (see Table 4.2). We then tested the reliability of the final constructs; all constructs appeared to be reliable, with Cronbach's alphas higher than 0.75 (see Table 4.2).

Table 4.2 *Instrument questionnaire*

Construct	Items	Scale	Cronbach's α
Policy knowledge	How familiar are you with... the plans of the national government regarding the transition towards sustainable heat. the plans of the municipality regarding the transition towards sustainable heat. the plans regarding the transition towards sustainable heat in the neighbourhood.	1 = very unfamiliar – 5 = very familiar	0.82

Table 4.2 *Continued.*

Construct	Items	Scale	Cronbach's α
Technical knowledge	How familiar are you with... the possible alternatives other than natural gas to heat houses in a sustainable way. the adjustments needed in houses for making them suitable for sustainable heat.	1 = very unfamiliar – 5 = very familiar	0.87
Environmental concerns	I think it is important to use renewable energy, such as energy from solar panels or wind turbines. I want to improve the environment. We should all contribute against climate change.	1 = totally disagree – 5 = totally agree	0.83
Attitude towards becoming natural gas free	I am positive about the idea that the Netherlands will be completely natural gas free in 2050. It is better for the environment if every household will be disconnected from the gas grid. I am proud of my neighbourhood being a frontrunner in the transition towards natural gas free. I think it is not fair that plans are being made for my neighbourhood as one of the first neighbourhoods of the municipality to be disconnected from the gas grid. (R)	1 = totally disagree – 5 = totally agree	0.87
Preferred engagement in the transition	How do you want to engage in the transition towards natural gas free in your neighbourhood? I want to be informed about the transition. I want to take part in the discussion about the transition. I want to engage in the decision-making process. I do not want to be actively involved. (R)	1 = totally disagree – 5 = totally agree	0.76

Table 4.2 *Continued.*

Construct	Items	Scale	Cronbach's α
Trust in actors (single-item questions)	To what extent do you trust the following actors in taking into account your needs and wishes in the transition? Municipality Civil neighbourhood council Housing corporation Energy company Net distributor	1 = no trust at all – 5 = a lot of trust	-
Areas of interest (single-item questions)	How important do you consider the following areas to be involved in? Financial aspects Technical aspects Choice alternative solutions Planning Communication	1 = not important at all – 5 = very important	-
Importance of characteristics of alternatives (single-item questions)	How important do you consider the following characteristics when choosing for an alternative for natural gas? Installation costs Utilization costs Communality Comfort of living Sustainability Long-term	1 = not important at all – 5 = very important	-

4.3.2 Respondents

The survey aimed at adult citizens in both neighbourhoods and was sent on paper together with a newsletter to every household in both neighbourhoods. Citizens could return the questionnaire by mail, hand it in at the community centres in their neighbourhood, or fill it out online (through a link provided in the questionnaire). More than 9,500 questionnaires were distributed (3,583 in the subsidized neighbourhood and 6,000 in the unsubsidized neighbourhood), of which 1,272 were returned. Questionnaires that were less than half completed were discarded and in total 1,245 questionnaires (619 in the subsidized neighbourhood and 626 in the unsubsidized neighbourhood) were used for the analysis.

Table 4.3 gives an overview of the respondents' background characteristics. The respondents ranged in age between 18 and 95 years old. A majority of the respondents who filled out the questionnaire were homeowners (62%). In the unsubsidized neighbourhood the percentage of homeowners (66%) was larger than in the subsidized neighbourhood (58%). Most of the homeowners were male (70%) and relatively highly educated (51%). Their average age was 56 years old. Tenants (38%) were in the minority. Most of the tenants rented their house through a housing corporation (90%). The male-female ratio was better in this group (54% male) than in the group of homeowners, they had an average age of 54.7 years old, and were less highly educated than homeowners (71% had a lower or intermediate educational level). In the subsidized neighbourhood there were relatively more tenants and lower-educated respondents than in the unsubsidized neighbourhood.

Table 4.3 *Background characteristics of the respondents*

	Homeowners subsidized	Homeowners unsubsidized	Tenants subsidized	Tenants unsubsidized
Homeowners vs. tenants				
Tenant	-	-	250	171
Private landlord	-	-	6	39
Homeowner	351	406	-	-
Gender				
Male	259	267	139	111
Female	89	130	115	95
Mean age (SD)	58.1 (14.1)	54.1 (15.5)	60.4 (15.8)	47.6 (19.4)
Educational level				
Low	26	34	74	37
Middle	135	167	132	80
High	183	199	46	86
Living situation	48	84	136	121
Living alone	10	17	19	19
Alone + children	172	160	90	41
Living together	115	124	11	12
Together + children	6	19	0	16
Other				

4.3.3 Results

To answer the research questions, we conducted various analyses in SPSS. First, we tested whether the perceptions on the various elements of the transition towards sustainable heat differed between homeowners and tenants, also looking for the role of the context (whether the neighbourhood received a subsidy for the transition towards sustainable heat). Second, we compared which variables explain homeowners' and tenants' overall attitudes towards becoming natural gas free.

4.3.3.1 *Comparison of perceptions on the transition*

To compare the mean scores of homeowners and tenants on the various constructs, and to see whether the neighbourhood influenced the scores, we conducted MANOVAs, which compares the perceptions of groups on more than one dependent variable. The variables included in one MANOVA should be related (moderate to strong correlation) (Pallant, 2013). Based on a Pearson correlation analysis, we found four groups of dependent variables with moderate to strong correlations with each other but not with the other variables. We therefore created four groups of variables and conducted four MANOVAs. These groups of variables were labelled as: (1) *attitudes towards the transition*, including environmental concerns, attitude towards becoming natural gas free, and the trust variables, (2) *knowledge about the transition*, including policy knowledge and technical knowledge, (3) *interest in the transition*, including preferred engagement and areas of interest, and (4) *importance of characteristics of alternatives*. The independent variables were homeowners versus tenants and subsidized versus unsubsidized neighbourhood.

Table 4.4 *Wilks' lambdas of multivariate analysis for four groups of variables*

	Wilks' lambda	F (df, error df)	Partial η^2
Attitudes towards the transition			
Homeowners vs. tenants	0.87***	27.17 (7, 1089)	0.13
Subsidized vs. unsubsidized	0.96***	7.42 (7, 1089)	0.04
Interaction effect	0.98**	3.44 (7, 1087)	0.02
Knowledge about the transition			
Homeowners vs. tenants	0.99***	9.17 (2, 1196)	0.02
Subsidized vs. unsubsidized	0.89***	72.83 (2, 1196)	0.11
Interaction effect	1.00	1.07 (2, 1196)	
Interest in the transition			
Homeowners vs. tenants	0.96***	8.60 (6, 1183)	0.04
Subsidized vs. unsubsidized	0.98**	3.91 (6, 1183)	0.02
Interaction effect	0.99**	3.00 (6, 1183)	0.02
Importance of characteristics of alternatives			
Homeowners vs. tenants	0.95***	10.90 (6, 1162)	0.05
Subsidized vs. unsubsidized	0.97***	6.89 (6, 1162)	0.03
Interaction effect	0.99**	2.91 (6, 1162)	0.02

Note: ** $p < .01$, *** $p < .001$

The multivariate analysis showed significant differences between homeowners and tenants on the combined sets of variables for each of the four groups of dependent variables (see Table 4.4). Furthermore, interaction effects were found for the combined sets of variables relating to attitudes towards the transition, interest in the transition, and importance of characteristics of alternatives (see Table 4.4). This outcome indicates that on these sets of variables, the differences between homeowners and tenants diverged in the two neighbourhoods.

When the results for the dependent variables were considered separately, significant differences between homeowners and tenants were found for all variables, except for environmental concerns (see Table 4.5). Most of the effect sizes were very small; however, for technical knowledge, attitude towards becoming natural gas free, trust in the civil neighbourhood council, engagement, and most of the areas of interest, small effects were found. For the difference in trust in the housing corporation the effect was moderate.

Homeowners and tenants had similar environmental concerns but were less convinced about becoming natural gas free. Regarding the latter, tenants were more positive than homeowners. Homeowners had slightly more technical knowledge and policy knowledge than tenants, but both groups indicated a low to moderate level of knowledge for both variables. Both homeowners and tenants felt a desire to be engaged in the transition, but homeowners had a stronger wish for this inclusion. They considered all areas of interest (financial aspects, technical aspects, choice for alternative solutions, planning and communication) to be more important to be engaged in than did tenants.

Homeowners and tenants also differed in their trust in the various actors involved in the transition. Tenants were more positive than homeowners and had a particularly high level of trust in the civil neighbourhood council. Homeowners only had positive expectations for the civil neighbourhood council and were relatively negative about all the other actors. They were most negative about housing corporations, as they did not think this actor would represent their interests. Tenants had considerably more trust in housing corporations.

When the respondents were asked about the characteristics that should be taken into account when choosing an alternative to natural gas, they thought that installation costs, utilization costs, comfort of living, sustainability and viability in the long term were all important to take into account. Whether the alternative can be a communal solution was considered slightly less important. Homeowners considered installation costs to be more important than tenants, and tenants considered sustainability and communality of the alternative to be more important than homeowners.

In both neighbourhoods, the respondents had a similar attitude towards be natural gas free. The subsidy given to one of the neighbourhoods to get the transition started apparently did not influence citizens' attitude about becoming natural gas free. However, respondents in the subsidized neighbourhood had more policy knowledge, slightly more technical knowledge, felt a stronger wish to be engaged in the transition, and were more interested in all thematic areas than those in the unsubsidized neighbourhood (see Table 4.5). In particular, the difference in policy knowledge was substantial. An explanation of the higher level of policy knowledge could be that to receive the subsidy, for the subsidized neighbourhood plans had already been made and the municipality communicated about them in various ways (newsletters, meetings, and website), while the municipality of the unsubsidized neighbourhood had communicated less about the transition. As plans in the subsidized neighbourhood were more specific than those in the unsubsidized neighbourhood, citizens may have felt a stronger need to be engaged. Additionally, the respondents from the subsidized neighbourhood had significantly more trust in the civil neighbourhood council than did the respondents in the unsubsidized neighbourhood. This higher level of trust can be explained by the presence of a very active council in the subsidized neighbourhood, which had existed for decades, while in the other neighbourhood, the civil council had been established just one year prior to the survey.

Various interaction effects were found between homeowners vs. tenants and subsidized vs. unsubsidized neighbourhood. These effects were found in environmental concerns, attitude towards becoming natural gas free, and trust in the municipality. Homeowners in the subsidized neighbourhood were more positive towards becoming natural gas free ($M = 3.28$, $SD = 0.90$) and showed greater environmental concerns ($M = 4.07$, $SD = 0.68$) than those in the unsubsidized neighbourhood ($M = 3.05$, $SD = 1.06$; $M = 3.98$, $SD = 0.84$). For tenants this was the other way around: The tenants in the unsubsidized neighbourhood were more positive about becoming natural gas free ($M = 3.53$, $SD = 1.00$) than those in the subsidized neighbourhood ($M = 3.49$, $SD = 0.90$). Furthermore, the tenants in the unsubsidized neighbourhood had more environmental concerns ($M = 4.22$, $SD = 0.83$) than those in the subsidized neighbourhood ($M = 4.02$, $SD = 0.82$). With regard to the respondents' trust in the municipality, homeowners in the subsidized neighbourhood were more positive than those in the unsubsidized neighbourhood, whereas tenants were more positive in the unsubsidized neighbourhood than in the subsidized neighbourhood. However, the effects of these interactions were extremely small (see Table 4.5). Additionally, interaction effects were found in the preferred level of engagement, the various thematic areas of interest (finances, technical aspect, and planning) and in the importance of characteristics of alternatives (installation costs, utilization costs, and communality). Tenants in the subsidized neighbourhood had a stronger need for engagement ($M = 3.33$, $SD = 0.79$) than tenants in the unsubsidized neighbourhood ($M = 3.10$, $SD = 0.86$), but this difference was less apparent between homeowners in the subsidized neighbourhood ($M = 3.66$, $SD = 0.75$) and in the unsubsidized neighbourhood ($M = 3.43$, $SD = 0.84$). The same pattern was found for the thematic areas of interest. With regard to the importance of the installation costs, homeowners and tenants in the subsidized did not differ, but homeowners in the unsubsidized neighbourhood found this characteristic significantly more important than tenants.

Furthermore, tenants in the subsidized neighbourhood gave a slightly higher score to the importance of the utilization costs and communality of the alternatives than homeowners in the subsidized neighbourhood, while this was the other way around for the unsubsidized neighbourhood. However, all of these interaction effects were extremely small (see Table 4.5).

Table 4.5 *Mean scores homeowners vs. tenants and subsidized vs. unsubsidized neighbourhoods*

	Homeowners	Tenants	Partial η2	Subsidized	Unsubsidized	Partial η2	Interaction Partial η2
Attitudes towards the transition							
Attitude natural gas free							
Environmental concerns	3.16 (1.00)***	3.51 (0.95)***	0.03	3.37 (0.92)	3.22 (1.07)		0.00*
Trust in municipality	4.02 (0.77)	4.11 (0.82)		4.05 (0.74)	4.07 (0.85)		0.01**
Trust in civil neighbourhood	2.84 (1.12)*	3.00 (1.15)*	0.01	2.91 (1.11)	2.90 (1.16)		0.00*
council	3.49 (1.08)***	3.77 (1.02)***	0.01	3.76 (1.08)***	3.44 (1.02)***		
Trust in housing corporations	2.45 (1.15)***	3.23 (1.16)***	0.09	2.82 (1.26)	2.70 (1.20)		
Trust in energy companies	2.58 (1.07)**	2.80 (1.13)**	0.01	2.73 (1.10)	2.60 (1.12)		
Trust in net distributor	2.61 (1.07)*	2.77 (1.14)*	0.01	2.71 (1.08)	2.64 (1.11)	0.02	
Knowledge about the transition							
Policy knowledge	2.98 (1.07)*	2.89 (1.10)*	0.02	3.30 (1.05)***	2.59 (0.99)***	0.10	
Technical knowledge	2.76 (1.17)***	2.48 (1.19)***	0.04	2.75 (1.17)**	2.56 (1.19)**	0.01	
Interest in the transition							
Preferred engagement	3.54 (0.81)***			3.52 (0.78)***			
Interest in financial aspect	4.15 (0.88)***	3.23 (0.83)***	0.04	4.13 (0.93)***	3.32 (0.86)***	0.02	
Interest in technical aspects	3.88 (0.96)***	3.89 (1.06)***	0.02	3.84 (1.00)***	3.97 (0.99)***	0.01	0.01**
Interest in choice alternative	4.08	3.54 (1.11)***	0.03	4.09	3.67 (1.06)***	0.01	0.01*
solutions	(0.87)***	3.79 (0.99)***	0.03	(0.89)***	3.85 (0.96)***	0.02	
Interest in planning	3.86 (0.94)***	3.68 (1.04)***	0.01	3.93 (0.90)***	3.65 (1.04)***	0.03	0.01**
Interest in communication	4.06 (0.96)**	3.93 (1.04)*	0.00	4.13 (0.92)***	3.89 (1.05)***	0.02	0.00*
Importance characteristics							
alternatives	4.37 (0.77)***	4.21 (0.91)***	0.01	4.38 (0.76)***	4.24 (0.87)***	0.01	0.01**
Installation costs	4.41 (0.70)	4.45 (0.73)		4.48 (0.66)**	4.36 (0.75)**	0.01	0.00*
Utilization costs	3.67 (1.07)**	3.86 (0.99)**	0.01	3.68 (1.04)	3.80 (1.04)		
Communality	4.35 (0.69)	4.31 (0.81)		4.35 (0.73)	4.31 (0.75)		
Comfort of living	4.16 (0.83)*	4.27 (0.84)*	0.01	4.19 (0.77)	4.20 (0.84)		
Sustainability	4.37 (0.79)	4.39 (0.81)		4.45 (0.71)	4.31 (0.87)		
Long term							

4.3.3.2 Antecedents of the attitude towards becoming natural gas free

To gain insight into the acceptance of the transition towards sustainable heat, we conducted regression analyses both for homeowners and tenants and for the subsidized and unsubsidized neighbourhoods. Attitude towards becoming natural gas free was used as the dependent variable, and the respondents' background characteristics (educational level, gender, and age), environmental concerns, policy knowledge, technical knowledge, and trust in various actors were used as the predictors. Additionally, in the regression analysis for homeowners vs. tenants, the type of neighbourhood (subsidized vs. unsubsidized) was included, and in the regression analysis for the neighbourhoods, homeowners vs. tenants was included. The results of these analyses are summarised in Table 4.6.

The percentage of explained variance was high in all cases (between 50% and 55%). For both homeowners and tenants, environmental concerns proved to be an important predictor of the attitude towards becoming natural gas free. Furthermore, in both cases trust in the municipality and trust in the civil neighbourhood council were significant antecedents. Some interesting differences between the two groups were found. For homeowners, policy knowledge played a significant role, while this was not the case for tenants. For tenants, trust in energy companies was a significant antecedent. Additionally, younger tenants were generally more positive about the transition than older tenants. No differences were found in the regression analyses of the subsidized and unsubsidized neighbourhoods. For both neighbourhoods, homeowner vs. tenant, environmental concerns, trust in the municipality, and trust in the civil neighbourhood council were significant antecedents of the attitude towards becoming natural gas free.

All regression analyses show that environmental concerns are an important antecedent of attitude towards becoming natural gas free. Furthermore, the analyses show that the municipality and civil neighbourhood council are perceived as important actors in the transition to sustainable heat. When the level of trust in these actors is high, the attitude towards becoming natural gas free is more positive. Interestingly, for tenants as well as for homeowners, housing corporations do not play a significant role. It was expected that this actor would be important especially for the tenants.

Table 4.6 *Results of the regression analysis for homeowners and tenants and subsidized and unsubsidized naighborhood (dependent variable: attitude towards becoming natural gas free)*

	Homeowners	Tenants	Subsidized	Unsubsidized
Subsidized vs. unsubsidized	- 0.04	- 0.05	-	-
Homeowner vs. tenant	-	-	- 0.07*	- 0.08*
Age	0.01	- 0.13**	- 0.07	- 0.02
Gender	- 0.03	0.05	0.03	0.04
Level of education	- 0.01	- 0.07	- 0.05	- 0.02
Environmental concerns	0.47***	0.51***	0.48***	0.50***
Policy knowledge	0.06	- 0.01	0.08*	- 0.02
Technical knowledge	- 0.01	- 0.04	- 0.04	0.00
Trust in municipality	0.27***	0.15**	0.19***	0.26***
Trust in civil neighbourhood council	0.09**	0.11*	0.11**	0.08*
Trust in housing corporations	0.02	0.07	0.03	0.03
Trust in energy companies	0.04	0.17*	0.11	0.08
Trust in net distributor	0.02	- 0.06	0.03	- 0.06
R^2	0.53	0.50	0.51	0.55
F	61.94***	35.88***	46.19***	55.01***
df	12	12	12	12

Note: Scores represent standardized coefficients; *p < .05, **p < .01, ***p < 0.001

4.4 Discussion

The aim of this research was to compare homeowner and tenant perceptions of the transition towards sustainable heat, and to study the influence of the local context, in terms of a subsidized versus an unsubsidized neighbourhood, on this perception. We conducted a mixed-methods approach, including focus groups with homeowners and tenants from a subsidized and unsubsidized neighbourhood and a large-scale survey study among homeowners and tenants from both neighbourhoods. Below, we first summarise and interpret the findings of both studies. We then address the limitations of our research and propose directions for future research. The section ends with practical implications that follow from our findings.

4.4.1 Main findings

The focus groups showed that homeowners and tenants differ in how they see their roles in the transition towards natural gas free. Although both groups see the municipality as the ultimately responsible actor in the process, tenants consider their housing corporation to be responsible for adjusting their homes, while homeowners feel responsible themselves. Homeowners feel that they lack a clear representation in the transition, are concerned about the power of housing corporations in the process, and feel uncertain whether they have the abilities to make the right decisions. Despite these differences in roles and responsibilities, the focus groups showed that homeowners and tenants consider similar themes to be important in the transition.

The comparisons of survey scores between homeowners and tenants revealed differences that correspond to their different roles. Tenants are more positive than homeowners about becoming natural gas free, as they might see fewer hurdles and costs in the process. They may expect the process to be guided by their housing corporation or landlord/lady and the immediate consequences of the transition may be less salient to them. This difference also reflects in the higher levels of trust tenants have in all parties involved in the transition. Homeowners, on the other hand, indicate to have more technical and procedural knowledge about the transition, have a stronger wish to be engaged in the process, and have more interest in every aspect of the transition than tenants do. This reflects their individual responsibilities in the transition to sustainable heat. When assessing the importance of characteristics of alternatives for natural gas, investment costs are more important to homeowners, whereas tenants take a somewhat broader perspective, with more attention for communality and sustainability.

As useful as it is to draw attention to such differences, it seems equally important to highlight that, given the effect sizes found, the differences are actually rather small. Although it is clear that homeowners, compared to tenants, have a stronger wish to be engaged in the process and are more interested in all aspects of the transition, tenants also find it important to be engaged and show interest in these aspects. In line with earlier research (Sagebiel et al., 2014) it seems important to engage citizens—not only homeowners but also tenants—in the transition process. In a similar vein, although investment costs are more important to homeowners than to tenants, tenants also appear to have an eye for them (which they presumably expect to see reflected in their monthly rent). And, likewise, homeowners also think that communality of alternatives for natural gas deserves attention. In all, the differences between homeowners and tenants must be seen as nuances, not as fundamental differences.

The regression analyses showed that similar antecedents matter for homeowners' and tenants' attitude towards becoming natural gas free. The most important antecedent for both groups is environmental concerns. This finding suggests that local energy transition projects need to be embedded in a broader context in which the challenge of climate change and the importance of a comprehensive energy transition is kept high on the societal agenda. Earlier research showed that homeowners' environmental concerns positively affects their willingness to adopt energy-efficient measures (Broers et al., 2019; Ebrahimigharehbaghi et al., 2019). Our study confirms this finding and shows that it also applies to tenants.

Trust in relevant actors is the other important antecedent for homeowners and tenants. Apparently both groups are not only affected by intrinsic considerations, but also by their trust in relevant actors. This finding confirms earlier studies showing that trust in actors involved is an important success factor for local energy projects (Bronfman et al., 2012; Liu et al., 2019; Shaw et al., 2015). Trust in the municipality is an important antecedent of residents' attitude towards becoming natural gas free. Both the focus groups and the survey showed that homeowners and tenants doubt whether the municipalities have the capacity to guide the transition and the willingness to consider their interests. The other significant trust variable, in the civil neighbourhood council, received much higher scores from homeowners and tenants. This may be because this actor is closer to the residents and has stronger ties with the neighbourhood involved. This finding confirms the results of Van der Schoor and Scholten (2015).

The regression analysis for tenants had two puzzling results. First, despite the prominence of housing corporations in the transition process, as underlined in the focus groups, trust in the housing corporation was not a significant antecedent of tenants' attitude towards becoming natural gas free. It is plausible, however, that this trust factor will become significant when the scope of the transition moves from the neighbourhood to the housing corporation. Second, tenants' trust in energy companies appeared to be a significant antecedent of their attitude towards becoming natural gas free. They may have thought of district heating as one of the plausible outcomes of the process.

Both the focus groups and the survey show that homeowners and tenants need more than a general story about the necessity of the energy transition. They also actively think about characteristics of alternative options, not only in terms of consequences for themselves but also as a solution to climate change, and do not take the sustainability and long-term viability of some of the proposed alternatives (district heating and bio-energy) for granted.

Even though it must be stressed that our study was a field comparison and not a quasi-experiment, our findings also shed some light on the effects of a national subsidy on the dynamics in a neighbourhood in transition. Residents from the subsidized neighbourhood scored higher on knowledge, preferred engagement, and interests than residents from the unsubsidized neighbourhood. Their response rate to our survey was also higher. This might be due to the more specific plans and communication activities within the subsidized municipality. However, the differences between the neighbourhoods were generally small, indicating that a generic subsidy may have more effects at the system level than on individual perceptions.

4.4.2 Limitations and future research

This research, however, does have some limitations. An important limitation involves the survey sample. Our response rate was 18% in the subsidized neighbourhood and 10% in the unsubsidized neighbourhood. Citizens who returned the questionnaire might be more interested in the topic and have more extreme opinions (in favour or against) than citizens who did not. This is a common problem with questionnaires, but it is something to consider when interpreting the results.

Second, the dependent variable of our study was attitude towards becoming natural gas free. While attitudes give an indication of people's acceptance of the transition towards sustainable heat, we did not measure behavioural intentions or actual behaviour. Citizens may agree with the policy of natural gas free, but this may not result in action (paying for insulation or adjustments, accepting higher costs, passively or actively supporting the transition). Acceptance is an important first step in motivating citizens to action, but future research should also include behavioural variables.

Third, we only compared the overall categories of homeowners and tenants, but there may be relevant variations within these categories. One can think of tenants renting from housing corporations versus tenants renting from private landlords/ladies. One can also think of homeowners in different price segments. Likewise, it may be interesting to differentiate more in types of homes, for instance comparing already insulated homes with poorly insulated ones. Future research could focus on further differentiating the findings in our study.

A fourth limitation is that our study involved cross-sectional data focusing on an early stage of the transition process. Future research should complement our findings by longitudinally analysing how the perceptions and behaviours of homeowners and tenants evolve over time. This can be done quantitatively (by administering the same questionnaire at subsequent stages in the process) or qualitatively (by following the transition processes in-depth in a limited number of households from both groups).

4.4.3 Practical implications

Our results provide several insights for local governments on how to engage residents in a transition towards sustainable heat. First, local governments should treat homeowners and tenants as important stakeholders and offer them to participate in the process. A low-threshold governmental body in the vicinity of the residents, such as a civil neighbourhood council, may play an invaluable role here. Second, even though their roles and responsibilities differ, homeowners and tenants do not seem to differ fundamentally in their views on the transition to sustainable heat. They may be approached in similar ways, with some small differences in emphasis. One such difference is that homeowners are not organized, feel like they are left to their own devices, and do not feel represented in the process. Third, it appears to be important for local projects to keep the societal issue of climate change and the nationwide challenge of the energy transition high on people's agenda. The degree to which people acknowledge the urgency of the challenge is strongly related to their attitudes in specific local projects. Fourth, it is important to realise that trust in the capability and benevolence of actors plays an important role in such transition processes. Actors responsible for the transition must actively work on their trustworthiness to the homeowners and tenants.

5

How can I contribute? Citizen engagement in the development of nanotechnology for health

5.1 Introduction

Various scholars have advocated for more substantive public engagement efforts in the developmental processes of science and technology. They argued that the general public should be included in the development of technological innovations in order to create new knowledge and add social value (e.g., Jasanoff, 2014; Rip, 2014; Wynne, 2006). Wynne (2006) underlined the importance of citizen engagement more than a decade ago, when he identified "an apparent institutional lack of ability to imagine that public concerns may be based on reasonable questions that are not being recognized and addressed" (p. 219). Eight years later, Jasanoff (2014) remarked in her reflection on the development of public understanding of science that not much has changed. She concluded that too often the general public has been treated as an entity that is ignorant and indifferent to science, while in reality people can add relevant insights. In a similar vein, Rip (2014) emphasized that responsible research and innovation (RRI) should not only be about a moral division in which scientists and other stakeholders advocate progress, and civil society actors add the 'responsible' components but also that societal actors jointly should inquire issues that are at stake.

While researchers agreed upon the added value of the inclusion of citizens as a worthy partner in the development of science and technology, little is known about the nature and content of citizens' input in this regard. Therefore, according to Jasanoff (2014) research should focus on actual public responses rather than on imagined outcomes. Due to the complexity of technological innovations, including their technicalities and the technologies' high degree of uncertainty and unpredictability (Krabbenborg, 2012), the question arises as to how the general public adds value to the development of technological innovations. In this study, we aimed to obtain more insights into citizens' contributions to future nanotechnologies in health. In the following, we will elaborate on different rationales for public engagement, the role of citizens in the development of science and technology and the context of nanotechnologies for healthcare applications.

5.1.1 Public engagement: from informing to co-creation

The importance of engaging the layman in the development of science and technology has been recognized for years, but the perspective of why and how to engage publics has changed (Bucchi & Neserini, 2008). Public engagement started in the 1970s as a way of informing and persuading the public about technological developments based on the so-call deficit model, due to increasingly critical citizen views on technological developments. It was assumed that these critical views towards science and technology were based on a lack of knowledge. That assumption changed in the 1990s when various studies showed that informing or persuading citizens did not suffice to increase acceptance for technological change, because the relation between knowledge and attitude is much more complex (e.g., Wilsdon & Willis, 2004). To increase citizens' trust in a new technology and enhance legitimacy of its governance, a dialogue model was adopted based on the idea that two-way communication between science and society would restore this trust (Bucchi & Nesirini, 2008; Dijkstra, 2008; Hennen & Pfersdorf, 2014).

Although the value of a dialogue between science and society has been recognized, the debate on genetically modified organisms (GMOs) in Europe showed that the crisis of public trust in the new technology and its governance was so deep, that also the view about restoring citizens' trust in science and technology through engagement started to change (Russel, 2013). Instead of technocratic governance of technology and top-down public participation, the emphasis was put on including societal norms and values in the development of science and technology through public engagement (Russel, 2013). This emphasis on inclusion of societal norms and values during the innovation process and the reflection of potential impacts of technological innovation has been labelled as responsible research and innovation (RRI) (Von Schomberg, 2012). As such, public engagement is considered a means to increase legitimacy of the innovation process and to create more socially robust innovations. Based on this view, new types of engagement, such as co-creation and co-production, have increasingly gained attention by researchers and policymakers. These types aim for substantial contributions of citizens when developing innovations (e.g., Gudowsky & Peissl, 2016; Gudowsky & Sotoudeh, 2017; European Commission, 2016; Polk, 2015; Voorberg et al., 2015). The European Commission, for instance, regards public engagement in RRI a means to "co-creating the future with citizens and civil society organizations, and also bringing on board the widest possible diversity of actors that would not normally interact with each other, on matters of science and technology" (European Commission, 2016, par. 1). Various calls within the Horizon 2020 programme, the European Commission's main funding programme for European research and innovation between 2014 to 2020, have promoted co-creation which includes different types of actors such as citizens (Gudowsky & Sotoudeh, 2017).

The idea of including different types of knowledge, other than those of experts, when developing technological innovations has existed for a longer time, but its focus was mainly on including end-users and not on citizens. For instance, Von Hippel (2005) solely referred to the end-users when he defined his concept of 'democratization of innovation'. Also, Prahalad and Raswany (2004) and Vargo and Lusch (2004) studied the added value of end-users in the development of innovations. In these contexts, co-creation is based on an economic rationale initiated by organizations to produce goods or services that are more efficient and effective rather than the creation of socially robust innovations. Also, in the area of medical research, end-users have been involved in the development of health technologies. For instance, patient organizations were active in shaping the agenda of research in fields of their concern (Buchi & Nesirini, 2008), patients were involved in the creation of clinical guidelines (Pittens et al., 2013), and care-pathways were co-created with patients (Petit-Steeghs et al., 2020). Although these studies provided relevant insights in public engagement, they address a type of public that has a clear relation with the technology and can, thereby, provide expertise from a user's perspective (Braun & Schultz, 2010). In technological innovations which can have a major influence on society, such as nanotechnology, however, the affected public can be every citizen. In order to develop such technologies in a more socially robust way, as emphasised in RRI, it is therefore not only relevant involve end-users, but also citizens.

5.1.2 Citizens and the development of science and technology

Some scholars have studied citizens' contributions to technological innovations and concluded that involving citizens in the innovation process has the potential to create more benefits than simply enhanced inclusion and accountability. Although citizens might not understand all technicalities of an innovation, they are able to formulate their needs, define conditions for use, and understand the innovation's potential societal impact (e.g., Arentshorst et al., 2016; Gudowsky & Peissl, 2016; Goisauf & Durnová, 2019; Lehoux et al., 2018). Jasanoff (2014) explained that as follows: "people may not understand the insides of the machinery of contemporary living (...), yet, most are well enough equipped to realise when things are not working as they should" (p. 23). Indeed, Lehoux et al. (2018) found in their study on future health technologies that citizens were able to define the context in which the technologies should be implemented. Citizens emphasised that the technologies should be embedded in professional care and that individual freedom and privacy should be protected (Lehoux et al., 2018).

Furthermore, citizens can provide novel insights into research and innovation since they may differ in their perspectives from experts. Repo and Matschoss (2019) found in their comparison of the experts' and citizens' vision of the future European research priorities that both groups approach the future from largely different perspectives. Citizen participation can therefore disrupt traditional research and innovation agendas and challenge conventional practices that rely on established norms defined by experts. Additionally, issues that might hamper the acceptance of an innovation can be identified, because citizens tend to be both more precautionary and more cautious than experts regarding the potential personal, social and environmental consequences of innovations (De Saille, 2015).

Although the studies provided insights in the added value of engaging citizens in the development process, a more systematic analysis of how citizens contribute to this process of technology development is lacking. For instance, regarding what aspects of technology citizens are able to contribute to. Since citizens have different perspectives than experts and add novel insights to the process, it is interesting to examine the nature and characteristics of these insights and perspectives.

5.1.3 The context of nanotechnology

Nanotechnology provides an interesting context for studying citizen contributions, as it is considered a promising technology, but its impact on society is unpredictable (Delgado et al., 2011; Krabbenborg, 2012). Due to its potential impact on society, it has become the leading field for activities and discussions about RRI (Rip, 2014). Nanotechnologies act as the basis for technology solutions across a range of industrial and societal challenges (Mangematin & Walsh, 2012). In the context of health, these solutions include new therapeutic interventions, new ways of monitoring health, new ways of diagnosing diseases, and personalised and targeted medicines. Although many products already contain nanoparticles (e.g., transparent sunscreen, scratch-resistant coatings, and water-repellent clothing), innovations that might radically change our society are still in their developmental phase. These innovations are often disconnected from the people who will be affected by them because they are being developed in laboratories and other secluded arenas (Foley et al., 2017). Hence, there is a need to engage the public in the development and implementation of nanotechnologies.

Although insights and knowledge have been collected on public engagement exercises in the field of nanotechnology (e.g., Delgado et al., 2011; Dijkstra & Critchley, 2016; Rip, 2014; Wickson et al., 2010), little attention has been paid to understanding the outcomes of these initiatives for the research and development of specific nanotechnologies (Shelley-Egan et al., 2018). Various studies have provided lessons learned regarding the organization of public engagement initiatives about nanotechnology. Dijkstra and Critchley (2016), for example, emphasized that deliberations about nanotechnologies should include the potential risks and benefits of their applications, because publics find both aspects important. Wickson et al. (2010) emphasized the diverse nature of nanotechnology and stated that public engagement activities should focus on specific applications rather than on nanotechnology in general. Delgado et al. (2011) advocated more upstream engagement activities, where empowered citizens provide input to the development of nanotechnologies. However, the authors warned that public awareness of nanotechnology is low. Therefore, they argued that engagement with citizens should be initiated by actors involved in nanotechnology (e.g., government, research, civil society organizations) and that citizens should be informed through visions or scenarios about future applications of nanotechnology (Delgado et al., 2011). While these findings provide relevant input for the setup of engagement exercises, there is a need to focus on the outcomes of public engagement and their (potential) effects on the development and implementation of the science or technology at hand (Jasanoff, 2014; Shelley-Egan et al., 2018).

5.1.4 Research question

In this study, we aimed to gain insights into citizens' contributions to the development of nanotechnologies for healthcare applications. We were interested in the aspects citizens could give suggestions to and the values underlying these suggestions. Within the context of health, some scholars have differentiated multiple aspects of technology development to obtain a better understanding of people's potential experiences with the technology (Koonce et al., 2008). These aspects include the 'design' connected to the artefacts of the technology, 'development' connected to the developmental process of the technology, 'implementation' connected to how the technology is implemented and how the actors are involved in this process, and 'utilization' connected to the aims of the technology and how it is being used (Majmudar et al., 2015; Sittig & Singh, 2010). These four aspects correspond with the technological innovation system (TIS) perspective on technologies, which approaches innovations as a socio-technical system and focuses on the activities in the development, diffusion, and utilization of new technologies (Bergek, Jacobsson, Carlsson et al., 2008). In this study, we use the four aspects of design, development, implementation, and utilization as an analytical framework to obtain a better understanding of citizens' contribution to the development of nanotechnologies for healthcare applications.

Furthermore, to understand how citizens contribute to the development of nanotechnologies, we analysed the underlying values. Most approaches to RRI emphasise that to be responsible, research and innovation need to address societal needs and challenges, anticipate potential problems and reflect on underlying values (e.g., Wickson & Forsberg, 2014). Porcani et al. (2016), who developed a roadmap for RRI, identified typical moral values that are important for research and innovation, such as autonomy, freedom, dignity, privacy, justice, well-being and responsibility.

5.2 Method

5.2.1 Design

The aim of this study was to explore citizens' potential for contributing to the development of nanotechnology by analysing to what technology aspect they are able to contribute to and based on what values. Eight extensive focus groups , which lasted approximately 6.5 hours each, with six to seven participants per focus group, and a total of 50 participants, were organized in the Netherlands. Following the insights of Wickson et al. (2010), who emphasized the diverse nature of nanotechnology and stated that public engagement activities should focus on specific applications rather than on nanotechnology in general, we selected future health applications of nanotechnology as input for the focus groups. The focus groups were moderated by trained professionals, and the setup of the sessions was derived from design-thinking methodology. This methodology includes four phases of exploration, ideation, prototyping and reflection, which , together, foster creativity and promote integration of different types of knowledge (e.g., Tohidi et al., 2006; Yoo et al., 2013). In the exploration phase, participants get to know each other and the topic. The ideation phase stimulates generating new ideas, which are further developed in the prototyping phase. In the reflection phase, participants reflect upon the output and process.

5.2.2 Future applications of nanotechnology

Based on a literature review and five interviews with experts from various sectors (a director of a research institute on nanotechnology, two senior policy advisors from the Ministry of Health, a senior advisor of a CEO of a technological start-up, and a head of innovation of a CSO), three of the most promising nanotechnologies in health were selected. These technologies included (early-) diagnostic devices, sensor technology for monitoring diseases, and regenerative medicines. Furthermore, several application contexts were defined, including the detection and treatment of cancer, monitoring and treatment of diabetes, and preventive healthcare. Based on the technologies and the applications areas, three future scenarios that can unfold in healthcare in 2030 were developed. The scenarios were written up as short stories (265-333 words) and illustrated with cartoons. The use of scenarios follows the research of Lehoux et al. (2018), who used scenarios to study the public's perception of the relationship between responsibility and prospective health technologies. In the current study, the scenarios were distributed to participants one week before the session and at the start of the focus groups.

5.2.3 Instrument

First, during the focus groups, the participants were asked to respond to future applications of nanotechnologies for health that were provided through the scenarios. This corresponded with the exploration phase, and participants became familiar with the technologies. Second, the participants were asked to give specific suggestions for the applications that were mentioned in the scenarios, which corresponded with the ideation phase. Third, based on the suggestions of the previous sessions the participants had to design their ideal technology, which was the prototyping phase. Fourth, participants were asked to reflect on the input given in the previous phases and to formulate messages for various stakeholders involved in the development of the technologies. The aim of these phases was to gain insights into the needs and values of citizens and to collect new suggestions about the development of future health nanotechnologies.

5.2.4 Participants

Dutch citizens (non-experts), who lived in different areas in the Netherlands, and were of different ages and mostly highly educated, and who were represented by an almost equal number of men and women, participated in this study (see Table 5.1, next page). The participants were recruited through leaflets in public places, social media posts and news items on websites of various health organizations and through diverse networks of the researchers. Participants were divided into eight groups based on their demographic characteristics, with the aim of creating diverse groups.

5.2.5 Analysis

Seven focus group sessions were recorded and transcribed. One session was not recorded due to a failure of technology, but the moderator took extensive notes. The transcripts consisted of discussions about the scenarios, messages to stakeholders, and explanations of the 'ideal technology'.

The coding was conducted by the first author and consisted of two rounds. In the first round, we coded for technology aspects that participants contributed to during the focus group session. These aspects were derived from the literature (Majmudar et al., 2015; Sittig & Singh, 2010) and included design, development, implementation, and utilization. During the coding, it became clear that in addition to these four aspects, suggestions were given to two other aspects: 'embeddedness in healthcare system' and 'communication about the technology'. Comments about the embeddedness of technology in the healthcare system were both about the context (system) in which the technologies were being developed and how the technologies could change the system. Comments regarding communication about the technology were about providing information and educating citizens about the technology. Furthermore, participants did not discuss for which aims the technologies could be used, which would be the 'utilization aspect', but focused on whether they wanted to make use of the technologies. Therefore, we changed 'utilization' into 'use' (see Table 5.2).

Table 5.1 *Participant characteristics*

	N	%
Gender		
Male	27	54
Female	23	46
Age		
18 – 24	7	14
25 – 34	17	34
35 – 49	8	10
50 – 59	9	18
60+	9	18
Education		
Low (primary and secondary education)	0	0
Middle (high school)	6	12
High (university, applied university)	44	88

The unit of analysis of the codes was the whole text part (transcribed discussion of a particular focus group session) that referred to a particular technology aspect. These text parts consisted of three to 20 sentences and were both based on input from one participant or multiple participants within one focus group session. In total 328 text parts were coded that referred to a particular technology aspect.

In the second round, we coded for values to which the suggestions on the technology aspects could be connected to and which can be seen as underlying motives. The values were inductively coded and included well-being, autonomy, privacy and security of data, accessibility, affordability, safety, and health (see Table 5.2). The unit of analysis of the values was every text part that referred to a particular value, which was between the one and five sentences. Those text parts co-occurred with a larger text part that referred to a particular technology aspect. However, not every text part referring to a technology aspect contained a reference to a value. In total 301 text parts were coded that referred to a value.

To indicate measurement consistency, inter-coder reliability was based on ten percent of the corpus. One round of coding was conducted with a social sciences researcher who was not involved in this study. This resulted in a good agreement (Cohen's kappa) on the two coding categories (see Table 5.2).

Table 5.2 *Codebook*

Category	Cohen's kappa	Code	Description
Aspects of the technology	0.94	Development of the technology	About future technologies or technological directions that might or could be developed / ethical aspects of the development of technologies / references to research / and advice or messages to developers and/or researchers.
		Design of the technology	Suggestions or comments about the design of a specific technology, reading device or interface of technology / comments about possible features and settings of a technology and its reading device / explanation of the design of a 'new' or 'ideal' technology.
		Implementation of the technology	How the technology could be implemented / how different stakeholders are included in the care loop and who will operate the technology / where the technology will be used or can be purchased / frequency of use of the technology (yearly, daily) / whether the technology is prohibited or not / and who will pay for it.
		Use of the technology	Only about intentions or attitudes regarding the willingness to use or not to use the technology, and argumentation or motives for the intention / influence of use of technology on well-being / often described from an individual perspective.
		Communication about the technology	Suggestions related to communication and education about the technology on an individual level, organizational level and societal level.
		Embeddedness of the technology in the healthcare system	Comments on the healthcare system and regulatory framework: how the healthcare system regulations should be changed if the technology were to be implemented or how the technology could change the healthcare system / often connected to the role of the government and insurance companies in the healthcare system / described on a generic level.

Table 5.2 *Continued.*

Category	Cohen's kappa	Code	Description
Values	0.68	Well-being	Whether the technology increases or decreases well-being (state or condition of happiness), including whether the use of it leads to stress and anxiety.
		Autonomy	Whether the technology provides self-determination over the body and ownership of data and whether (potential) users have the freedom of choice in using the technology.
		Privacy and security of data	Whether the technology collects and stores data and whether it provides possibilities for sharing data in a secure and safe way.
		Affordability	Whether the technology is affordable to purchase and other financial aspects related to the technology and the healthcare system.
		Accessibility	Whether the technology safeguards or enhances accessibility to healthcare and health or whether it leads to polarization (poor vs. rich, old vs. young, digital skilled vs. unskilled).
		Safety	Whether the technology is safe to use, including the interpretation and reliability of data and potential harmful consequences.
		Health	Whether the technology improves (physical) health, including treatment of diseases.

5.3 Results

The results are based on all contributions from the focus group sessions, without connecting the contributions to the specific phases of the focus groups.

5.3.1 Aspects of nanotechnologies

Participants gave feedback on the six distinguished aspects of the nanotechnologies: implementation, use, system, development, design, and communication (see Table 5.3), with the main emphasis in all eight co-creation sessions being on the implementation of different nanotechnologies and the use of these technologies. Moderate attention was given to suggestions on the healthcare system and the development of nanotechnologies, while the least emphasis was placed on the design of nanotechnologies and communication about nanotechnologies.

Table 5.3 *Frequency of coded text parts that refer to the technology aspects*

Aspect	Frequency	Illustrative quote
Implementation	101	*"I get the impression that these monitoring and diagnostic devices lead to self-medication, which I dislike. There are so many people who are not able to do this, so we should ensure that a medical professional operates the technologies."*
Use	92	*"I believe that I would live constantly in fear about my health if I were to use such a monitoring device. You never know when an anomaly will be detected. This also relates to the reliability of the technology. How do you know for sure that the data are measured in a reliable way?"*
System	55	*"Imagine if everyone were to make use of these monitoring and diagnostic devices. It would probably place a huge burden on the healthcare system, both financially and in terms of labour, as all these people would go to a health professional in case of bad results."*
Development	47	*"When developing these technologies, researchers should take into account the human dimension. People should not be treated as 'objects' that need be cured but as human beings. This will enhance societal acceptance."*
Design	23	*"I would find it much more logical if the monitoring device were to only give a signal if something were wrong, and thereby would not continuously focus attention on your health. But this is more of a technical solution, of having the sensors in your body, but not being continuously aware of them."*
Communication	10	*"I don't think we can stop these technological innovations. Therefore, I think we should educate and inform citizens, in order to prepare them for making decisions about the use of these technologies."*

When discussing the 'implementation' and 'use' of nanotechnologies, participants mainly referred to monitoring and diagnostic devices. Three main subjects were associated with implementation: 1) who should operate the technology (e.g., health professionals or citizens themselves), 2) accessibility to the technology (e.g., everyone, voluntary access, and frequency of access), and 3) how health data should be managed. These topics often related to participants' concerns about a decrease in well-being. When participants referred to the 'use' aspect of the technologies, they mostly discussed whether they wanted to use the technologies from their own perspective. In this regard, the fear that the technologies would have a negative influence on well-being was mentioned. Additionally, some, but fewer, references were made to how the technologies could improve the participants' health and whether the technologies were safe to use.

Participants referred to 'embeddedness in the healthcare system' and 'development' of nanotechnologies when they mentioned criteria to be taken into account to make future healthcare and/or health technologies acceptable. Discussions about the healthcare system were often related to the possibility of transforming the system from treatment-based healthcare to preventive healthcare. Participants agreed that keeping healthcare affordable and therefore accessible to everyone should be the main motivation. In relation to the 'development' of nanotechnologies, participants discussed criteria to be taken into account by researchers and businesses. The participants emphasised that in the developmental process, these actors should focus on the potential societal implications of the technology, the use of the technology, and the data generated by the technology.

Participants provided few suggestions for the design of and communication about nanotechnologies. The contributions that were given regarding the design aspect mainly related to the reading of the monitoring and diagnostic devices on which the data would be displayed. Participants connected their suggestions to an increase in well-being (i.e., design that prevents being constantly aware of health data) and safety (i.e., little room for misinterpretation and ambiguity in reading the data). Suggestions on the communication aspect were about how to inform and educate the general public about the nanotechnologies. These suggestions mainly involved increasing societal acceptance and empowering citizens in making informed decisions about whether to make use of the technologies.

5.3.2 Values

Participants mentioned various values in the context of future nanotechnologies, including well-being, autonomy, privacy and security, affordability, accessibility, safety and health. The participants mentioned these values across various technology aspects, but some values were more often mentioned in relation to a particular aspect than other values (see Table 5.4). These values can be regarded as the underlying motives for the needs and suggestions mentioned by the participants.

Table 5.4 *Co-occurrence of values and aspects*

Values: / Aspects:	Well-being	Autonomy	Privacy + security	Afford-ability	Acces-sibility	Safety	Health
Implementation	16	28	20	9	18	9	10
Use	34	12	8	7	8	13	13
System	2	11	9	19	8	2	5
Development	2	2	4	3	2	6	2
Design	7	1	2	0	0	4	0
Communication	0	3	0	0	0	0	0
Total	61	59	43	38	36	34	30

5.3.2.1 Well-being

Well-being was most frequently referred to in the focus groups, and it was mainly related to monitoring and diagnostic devices. Regarding the early diagnostic devices, a number of participants were concerned that insights into the high risk of diseases in an early stage would negatively affect their well-being. This was especially the case for diseases for which no cure has been developed yet (e.g., Alzheimer's disease). Additionally, a majority of participants thought that diagnostic devices that have to be operated by patients at home could lead to stressful situations, as citizens might not know how to deal with negative outcomes. A few participants compared the devices to a home-test for sexually transmitted diseases (STDs), which are already on the market, but which they did not want to use, because they are afraid of the outcomes. Participants suggested that when implementing the technology, the health professional should operate the diagnostic devices because he/she can provide mental care and solutions for a treatment plan in case of negative outcomes.

When discussing monitoring devices, almost all participants agreed that they disliked the idea of being constantly aware of generated health data. They thought that even though awareness of health data could lead to a better lifestyle and therefore improve their health, it would negatively influence their well-being. Hence, they were hesitant to make use of the devices. One of the participants stated, *"I wouldn't want to use it, I would go mad if I would be aware of my health every day"* (Respondent 4, Group 2). A suggestion was made to design the monitoring device in such a way that users would only obtain a signal when an anomaly was detected. Various participants compared the device with news apps, which give push messages in case of important news events. Additionally, some participants suggested implementing monitoring technologies in such a way that the data generated by the technology would be linked to a reading device that is operated by a health professional who interprets the data and informs the user.

5.3.2.2 *Autonomy*

When referring to autonomy, several participants emphasised that freedom of choice in using nanotechnologies for health should be safeguarded at all times. Others challenged this notion by making a comparison with vaccinations and thought that some technologies should be made mandatory if public health would be in danger. These aspects relate to the *implementation* of nanotechnologies. The debate about freedom of choice arose from the fear that the government or health insurance companies could force the use of early diagnostic and monitoring technologies to transform the healthcare system from treatment-based care to preventive healthcare (system). One participant, for example, stated, *"these technologies might potentially lead to an unjust society, where the insurance company can decide what you need to do"* (Respondent 3, Group 4).

Furthermore, autonomy was mentioned in relation to monitoring and diagnostic devices, often when discussing implementing these technologies. Some participants thought that it would be a good development if citizens had more control in using and operating health technologies, since it would provide them with more autonomy. The participants made a link to pregnancy tests, which they said empowered women. Others thought that citizens' autonomy in operating health technologies should be limited and that the health professional should be included in the care loop, for the sake of citizens' well-being (less awareness of health data) and to prevent misinterpretations of data.

5.3.2.3 *Privacy and security of health data*

Additionally, the privacy and security of health data were mainly linked to monitoring and diagnostic devices. Many participants were afraid that the data generated by these devices would be shared with health insurance companies, who could use the data to adjust their premiums (*system*). An illustrative comment made by one of the respondents was that *"I believe it [the monitoring device] is very sensitive for privacy issues. What if health insurance companies will pay the producers of the device and will get access to the data? Who will safeguard this?"* (Respondent 1, Group 1). Some participants made an analogy with the electronic patient record, which has a controversial history in the Netherlands. Participants brought up that when developing monitoring and diagnostic devices, developers should ensure that the data are collected and stored in a secure way. Additionally, when implementing the technology, the government should ensure that citizens own their data themselves and can decide whom to share it with.

5.3.2.4 *Affordability*

Every participant emphasised that the technologies should be affordable for everyone. In this context, the possibility of transforming the healthcare system from treatment-based healthcare to more prevention-based healthcare with monitoring and diagnostic devices was discussed and whether this would decrease or increase the financial burden. Some participants argued such transformation would decrease costs, since diseases would be diagnosed at an earlier stage and the lifestyle could be better adjusted. Other participants thought that such a transformation would make healthcare more expensive, because people would become more aware of their health. Hence, participants emphasised that an important criterion for using nanotechnologies is whether they safeguard or increase the affordability of healthcare.

5.3.2.5 *Accessibility*

Many participants emphasised that health technologies should be accessible for everyone and should not lead to polarization in society. The participants feared potential polarization in two domains: rich versus poor and digitally-skilled people versus non-digitally skilled people. When implementing expensive technologies such as regenerative medicines, the technologies should be available to everyone and not only to the rich. Some participants compared the new technologies with donor organs and argued that in the case of limited availability, access to regenerative medicines should be decided based upon health indicators and not based upon financial means. Furthermore, a number of participants were afraid that monitoring and diagnostic devices that required the skills of people to read and interpret the data might limit access to these technologies for less educated and less digitally-skilled people. Therefore, the participants advocated including the health professional in the care loop when implementing the device. One of the participants argued that *"you need to have a certain level of intelligence to understand the data provided by this technology. A general practitioner can give you a clear consultation based on the data, but the technology itself can't"* (Respondent 3, Group 2).

5.3.2.6 *Safety*

Safety was less frequently mentioned. When participants referred to safety, they often discussed whether it was safe to use diagnostic and monitoring devices, as they were afraid that the data would not be reliable or could lead to misinterpretations. Some participants therefore thought it was safer to implement the devices in a healthcare context. An illustrative comment about this value is the following: *"I believe researchers should take into account the reliability issue of data. Citizens don't know how to deal with this"* (Respondent 1, Group 4). Additionally, participants had doubts about the safety of *using* regenerative medicines, because they had little knowledge about them. One participant said, for example, *"personally, I wouldn't make use of it because you don't know what the risks are. Before bringing such a technology [regenerative medicines] to the market, you need to have more knowledge about the risks"* (Respondent 6, Group 2).

5.3.2.7 *Health*

Participants also hardly mentioned 'health' as a value. When the participants referred to health, it was mainly related to monitoring and diagnostic devices and connected to preventive healthcare. Some participants hesitated to make use of these devices, as they doubted whether the use would improve their health. The participants feared that people would only rely on the technology and no longer on their intuition. One of the participants made a comparison with navigation systems: *"It is similar to navigation systems that calculate your route, and we just blindly follow the instructions"* (Respondent 2, Group 1). Others saw clearly added value of the technologies for their health. One respondent said, *"a focus on preventive health seems really* *valuable to me, you know immediately when something is wrong and can anticipate"* (Respondent 2, Group 2).

5.4 Discussion

We summarise and interpret the main findings of this study below. Subsequently, we address the limitations of the study and propose directions for future research. The section ends with the implications and recommendations that follow from our findings.

5.4.1 Main findings

In the extensive focus groups on nanotechnologies for healthcare applications, participants deliberated on a broad range of technology aspects. The participants provided suggestions on the implementation and use aspects and approached them from a user's perspective, because they imagined themselves as users of the nanotechnologies and defined the circumstances and conditions (the implementation aspect) under which they were willing to use these. Furthermore, participants substantially contributed to the embeddedness of the technology in the system and the development aspects, which they approached from a societal perspective. The participants understood how nanotechnologies could influence society as whole and were able to comment at this higher level of abstraction. For example, the participants discussed the potential of monitoring and diagnostic devices for changing the healthcare system from a 'cure-based system' to a 'prevention-based system'. Little attention, however, was given to the design aspect of the technologies, which was mainly connected to the artefacts of the technologies and the communication aspect.

When looking at the values that underlay the contributions, all values were substantially referred to, but well-being was mentioned most frequently and safety and health were mentioned the least. Most suggestions related to the participants' concerns. Remarkably, participants showed relatively few concerns regarding health and safety, which implies a high level of trust regarding the value of the technologies. Instead, the participants were concerned that the technologies would negatively influence their well-being. For instance, the participants worried that monitoring and diagnostic devices might lead to continuous awareness of health indicators and/or potential misinterpretations of data. Therefore, they suggested that a health professional should be included in the operation of the devices. Additionally, participants expressed fears that the devices could be forced upon them for the sake of transforming healthcare from a care-based system to a more 'preventive-based' healthcare system and that this would threaten their autonomy. Another concern was that insurance companies could make personal profiles based on the collected health data, which could influence premiums and access to healthcare. Participants emphasised that freedom of choice should always be provided and that users of the technologies should have ownership of their data and the ability to decide which data to collect, store, and whom to share the data with.

Interestingly, most of these suggestions were given in relation to monitoring and diagnostic devices. Participants found it much easier to understand the working principles of these technologies and were better able to relate them to their own lives than they did to regenerative medicines. When discussing diagnostic and monitoring devices, the participants made various analogies with existing technologies that they were familiar with, such as the benefits and negative aspects of pregnancy tests, electronic patient records, navigation systems, and vaccinations.

5.4.2 Theoretical implications

Our research shows that citizens can valuably contribute to the development and implementation of technological innovations. Although some scholars have already emphasised the added value of citizens in the development of technologies (e.g., Gudowsky & Peissl, 2016; Jasanoff, 2014), they have mainly emphasised that citizens are able to judge the acceptability and desirability of potential consequences. Our study not only shows that citizens are indeed able to judge the effects of the technologies on their personal life (from a user's perspective) and on society (from a societal perspective) but also shows that citizens are able to give specific suggestions to a variety of aspects of the technologies, including their use, implementation, embeddedness in the system, development, design and communication about the technologies.

The suggestions were based on a number of underlying values. Interestingly, well-being and autonomy were most frequently referred to when discussing future health technologies, and there was less emphasis on the traditional values of safety and health, which are often considered important indicators for assessing the desirability of nanotechnologies (e.g., Buckley et al., 2017; Peterson et al., 2007). An explanation could be that the technologies that the citizens mostly discussed, which were monitoring and diagnostic devices, were in vitro technologies that were developed for the prevention and treatment of diseases. Therefore, citizens might have been less concerned about the safety and health of these technologies. In general, citizens tend to put less emphasis on safety and health risks in the context of nanotechnologies for health, than, for example, in food or cosmetics (Capon et al., 2015). Our study shows that although health and safety risks are less of an issue, other values should be taken into account when assessing and developing nanotechnologies for health. Furthermore, our study shows that the importance of the values differs per technology aspect. For example, well-being is an important motive when deciding whether to use a technology, whereas autonomy, privacy and security, and accessibility are important when implementing a technology. These aspects help to prioritize the values for the actors involved in the different aspects of the technologies.

Although participants were able to contribute to future nanotechnologies in health, their ability to provide suggestions differed per application. Participants mainly provided suggestions on technologies that they could relate to their daily lives, and they used analogies with existing technologies to do so. These findings are in line with previous studies, which indicate that citizens use analogies with familiar objects, notions and technologies as a sense-making strategy (e.g., Davies, 2011; Marcu et al., 2015). However, as Schwarz-Paschg (2018) noted, analogies are not just used for sensemaking but are also a rhetorical strategy used by citizens to strengthen their suggestions and arguments.

5.4.3 Limitations and future research

Some limitations of this study must be taken into account. First, the participants were predominantly highly educated. While the participants were able to give their suggestions on different aspects of nanotechnologies, less educated participants might have had more difficulties in doing so. Second, the sample consisted of 50 participants, who were equally divided based on age, gender, and rural/urban living area. However, there are other variables that could also influence participants' opinions. Jasanoff (2014) reminded us in her essay that there is no such thing as the 'public', which we should be aware of when generalizing results. Nevertheless, the qualitative research setting of this study with 50 participants divided over eight groups provides a great number of participants to draw conclusions from. Third, the participants had little knowledge about the discussed nanotechnologies, which is why we used scenarios to inform them about these technologies. While different aspects of the technologies were highlighted in the scenarios, it is difficult to formulate the scenarios in a totally neutral way, and this may have influenced the discussions. Nevertheless, participants were free to choose the focus of the discussions and selected the issues they wanted to discuss themselves.

5.4.4 Conclusion

In an open discussion about nanotechnologies for health applications citizens were able to provide suggestions for a variety of technology aspects. However, the participants mainly emphasized the personal and societal perspectives and less the technical aspects. Their suggestions were mainly based on concerns about the potential effects of the technology, and the underlying motives include values such as well-being, autonomy, and privacy. When developing and implementing nanotechnologies for health, especially technologies that collect health data, involved actors should take these values into account. For policymakers and CSOs, the values provide issues to be put on the agenda when discussing the implementation of technologies. Additionally, the suggestions show that researchers and product developers should not merely focus on technical aspects but always take into account personal and societal aspects when developing novel technologies that might have a major influence on society.

6

Co-creation in support of responsible research and innovation: An analysis of three stakeholder workshops on nanotechnology for health

6.1 Introduction

The potential contribution of 'outsider perspectives' to the production of legitimate, responsible, and socially robust knowledge and innovation has been emphasized in science and technology studies (STS) (e.g., Jarmai & Vogel-Pöschl, 2020; Jasanoff, 2014; Reed et al., 2018). Co-creation, a form of collaboration in which relevant stakeholders jointly generate meaning and value, has increasingly received attention as a way to enhance the responsiveness of research and innovation. Various scholars have applied the concept of co-creation in studies on the robust and legitimate development of knowledge, research, and innovation (e.g., Engels et al., 2019; Gudowsky & Peissl, 2016; Gudowsky & Sotoudeh, 2017; Mauser et al., 2013; Polk, 2015; Voorberg et al., 2015). Furthermore, co-creation has been proposed as an instrument to support research and innovation policy. The European Commission, for example, uses the concept of co-creation in their definition of public engagement in responsible research and innovation (RRI), which they define as 'co-creating the future with citizens and civil society organizations, and bringing on board the widest possible diversity of actors that would not normally interact with each other, on matters of science and technology' (European Commission, 2016, par 1). Building further on this perspective, various calls within Horizon 2020, the European Commission's main funding programme for European research and innovation between 2014 and 2020, has promoted co-creation, including different types of professional and societal stakeholders, such as citizens, users, academia, social partners, public authorities, businesses, creative sectors, and social entrepreneurs (Gudowsky & Sotoudeh, 2017).

Despite the increase in attention, the precise role of co-creation in supporting RRI is not fully understood. Since co-creation has been applied in different domains, with different aims, and with different types of publics, there is a need for more clarity regarding the possible contributions of co-creation in the context of research and innovation. This paper explores the potential role of co-creation in fostering RRI by analysing three co-creation activities with different types of stakeholders in the area of nanotechnology and health. Below, we first describe the origins of and rationale behind co-creation in Section 6.1.1. Then, we discuss co-creation in the context of research and innovation (Section 6.1.2). Finally, we present our research question and the research context in Section 6.1.3.

6.1.1 Origins of and rationales behind co-creation

Co-creation has its origins in business and public policy contexts, but it has also been applied in other domains (Gudowsky & Sotoudeh, 2017). It describes a shift in thinking from the primary enactors (producers, policymakers or innovators) as definers of value to a more participative process in which customers, citizens, or other stakeholders together generate and develop meaning and value (Ind & Coates, 2013). In this process, value and meaning can be approached in two ways: (1) creation of meaning and value through the interaction itself and (2) the creation of value to the (new) product, policy, or innovation.

In business contexts, those aims often have been approached separately and translated into the creation of a meaningful relationship between customers and the creation of optimized products. The difference between these two aims lies in whether the focus is on the customer (relationship) or on the product itself. A meaningful relationship can be achieved as individuals are linked to companies through social interaction in terms of brand awareness and service experience; by means of co-creation, companies intensify the interaction and thereby possibly create a positive brand awareness (Ind & Coates, 2013). Furthermore, products always include service elements as it is their usage that matters. By focusing on this usage, the value is not inherent to the product as such but to the experience customers have with the product. Through co-creating these service elements with customers, customers feel more attached to the product, which may positively affect their experience of these products and the organization (Prahalad & Ramaswamy, 2005; Vargo & Lusch, 2004). The other approach to co-creation in this context revolves around the quality of the products themselves (Ind & Coates, 2013). This form of co-creation is at the front end of product development and focuses on the added value to these products (Prandelli, Verona, & Raccagni, 2006). Von Hippel (2004) referred to this type of co-creation when he introduced the term 'democratization of innovation,' explaining how co-creation with (potential) end-users of a product is based on an economic rationale and initiated by companies to produce goods more effectively and efficiently. The underlying assumption is that users bring in another type of knowledge than experts, which adds value to the product (Von Hippel, 2004).

In public policy contexts, both aims of co-creation have been emphasized as well. De Jong et al. (2019) stated that co-creation can lead to (1) better policy decisions based on richer input and (2) public support for government policy through active participation. Voorberg et al. (2015) distinguished different roles of citizens in the policymaking process: citizens as initiators, co-designers, and co-implementers. In the first type of co-creation, citizens identify problems in need of government measures; in the second type, citizens are asked to generate or prioritize ideas or solutions; and in the third type, citizens decide on or shape the execution of government policy (Voorberg et al., 2015). In theory, the two aims of co-creation can be compatible in the policy context, but in practice, policymakers often focus on the second aim and set up co-creation activities to create acceptance and legitimacy for their policies (Silverman et al., 2019). In her influential work on citizen participation, Arnstein (1969) emphasized that public participation should not just be an 'empty ritual' for creating legitimacy but should give real mandate to citizens. She emphasized that "participation without redistribution of power is an empty and frustrating process for the powerless" (p. 216). Citizens engaged in co-creation processes should have an actual say in the policymaking process.

6.1.2 Co-creation in support of responsible research and innovation

In the context of science and technology, co-creation has been used by aiming for a legitimate innovation trajectory and for robust knowledge and innovation (e.g., Engels et al., 2019; Gudowsky & Peissl, 2016; Polk, 2015). In this context, Voorberg et al. (2015) defined co-creation as “the creation of long-lasting outcomes that aim to address societal needs by fundamentally changing the relationships, positions and rules between the involved stakeholders, through an open process of participation, exchange and collaboration with relevant stakeholders, including end-users” (p. 1334). This definition of co-creation closely relates to Von Schomberg’s (2012) definition of RRI: “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” (p. 9). In both definitions, the emphasis lies on interactions between different types of actors or stakeholders and the changing responsibilities and relationships between these stakeholders in the innovation process, from a top-down process to mutual responsibility. Furthermore, both Voorberg et al. (2015) and Von Schomberg (2012) focused on legitimacy and on the value of innovation.

To gain a better understanding of how to bring RRI in practice, Stilgoe et al. (2013) developed a framework based on four integrated dimensions: reflexivity, inclusion, anticipation, and responsiveness. Reflexivity focuses on the involved actors in the innovation trajectory and asks scientists and innovators to look beyond their key responsibility for innovation development by opening up their innovation trajectory and reflecting upon their moral and societal responsibilities (Stilgoe et al., 2013). Inclusion concerns the engagement of various stakeholders, including citizens, in the innovation trajectory, which enhances the legitimacy of the innovation (Stilgoe et al., 2013). Anticipation involves considering the potential impacts of innovation and discussing possible desirable futures with societal actors, which can be achieved through public engagement activities (Stilgoe et al., 2013). Responsiveness includes ‘responding’ to societal needs and values and ‘reacting’ in adjusting the innovation based on these and values (Stilgoe et al., 2013). Foley et al. (2016) called this last dimension ‘adaptation,’ arguing that adaptation implies intentionality among stakeholders and a course of action based on experimentation, while responsiveness may be limited to a rather haphazard response of stakeholders to societal needs and values (Foley et al., 2016). According to Stilgoe et al. (2013), the four dimensions together lead to a legitimate innovation process and robust innovations (Stilgoe et al., 2013). Co-creation with different types of stakeholders seems to reflect these dimensions. However, it is unclear how to design such co-creation processes.

6.1.3 Research question and context

In this research, we combined the insights of studies on co-creation with those of the literature on RRI. We studied the following research question: How can co-creation with stakeholders foster responsible research and innovation by aiming for a legitimate innovation trajectory and/or added value of the innovation? Stilgoe et al.’s (2013) four dimensions—reflexivity, inclusion, anticipation, and responsiveness—were used to specify ‘responsible’ in RRI in practice. However, following Foley et al. (2016), we replaced responsiveness with adaptation, which suggests a more conscious process of adapting innovations based on co-creation outcomes and as such better reflects the aim of adding value to innovations.

The present study was conducted as part of the European Horizon2020 project GoNano, which aims at aligning future nanotechnologies with societal needs and values through co-creation. The GoNano project is based on the belief that research and innovation can benefit from being more open to societal needs and concerns through co-creation with relevant stakeholders along the value chain. The aim was to explore how different types of stakeholders can contribute to the development of future nanotechnologies in the areas of health, food, and energy. Our research focused on the health context. Nanotechnology is considered a promising technology, but its impact on society is unpredictable (Delgado et al., 2011; Krabbenborg, 2012). At the same time, nanotechnologies may underlie technological solutions for a range of industrial and societal challenges (Mangematin & Walsh, 2012). In the context of health, these solutions include therapeutic interventions, ways of monitoring health, ways of diagnosing diseases, and personalised and targeted medicines.

Although many products already contain nanoparticles, most innovations that might radically change society are still in their developmental stage. These innovations are often out of sight for the people who will be affected by them because they are being developed in laboratories and other secluded arenas (Foley et al., 2017). However, there are fears that as soon as the technologies will be implemented and commercialised, they are met with public resistance, as was the case with genetically modified organisms (GMOs) (Russel, 2013). Concerns about nanotoxicity and environmental impact, regulatory hurdles and uncertainty, and concerns about falling public confidence have fostered the endeavours of developing nanotechnologies in a responsible way. In fact, nanotechnology is considered the leading field for activities and discussions about RRI (Rip, 2014). In their analysis and reflection of RRI initiatives on nanotechnology, Shelly-Egan, Bowman and Robinson (2018) found that research into what should constitute RRI has received substantial attention, but the actual uptake of RRI by relevant actors and the actual effects of RRI on practices of researchers and innovation actors remain unclear. In this research, we address this by analysing how co-creation can foster RRI and lead to legitimacy and added value of the innovation.

6.2 Method

6.2.1 Design

To answer our research question, we compared and analysed three co-creation workshops on nanotechnologies for health, which were organized in the Netherlands. Various representatives of stakeholder groups participated in those workshops, including researchers, citizens, policymakers, CSO representatives, and business representatives. Each workshop lasted approximately 4.5 hours and followed the same methodology based on the general principle of design thinking (Tohidi et al., 2006; Yoo et al., 2013).

The workshops were preceded by an interview study with experts (N = 5) to identify the most promising nanotechnologies for health and a face-to-face consultation with citizens (N = 50) to collect their societal needs and values regarding those technologies. Based on these studies, thematic areas and/or applications were selected for the co-creation workshops with the stakeholders. These included monitoring and diagnostic devices for diabetes patients, sensor technologies for better detection of cancer, and improvements to policymaking for nanotechnologies. Furthermore, the output of the citizen consultation was used to anticipate the potential impacts and desirable futures of the technologies discussed in the stakeholder workshops. This output existed of values defined by citizens and included well-being, autonomy, privacy and security of health data, affordability of healthcare, accessibility of healthcare, safety, and health. Furthermore, citizens formulated specific needs when developing nanotechnologies for health, that is, to focus on prevention of diseases, to limited continuous awareness of health data, to safeguard ownership of data, to include the health professional in the care loop (monitoring and diagnosis of diseases), to focus on the usability and potential implications of nanotechnologies and to educate and inform citizens about health technologies.

6.2.2 Participants

An important factor for setting up a co-creation process is to identify and select the stakeholders to engage with. For the three co-creation workshops, stakeholders were selected based on a combination of a normative and instrumental stakeholder approach. First, a categorization was made of relevant stakeholder groups involved in the development of science and technology, which included citizens, researchers, policymakers, businesses, and CSOs. At the three workshops, a mixture of stakeholders from these groups were selected. Identifying and inviting stakeholders based on their organizational characteristics is based on a normative stakeholder approach, as it focuses on a representative sample of relevant groups in society aiming at inclusiveness (Jiya, 2019; Reed et al., 2009;). Second, following an instrumental stakeholder approach, we identified key stakeholders who had legitimate interests in the topics of the co-creation workshops (Jiay, 2019; Reed et al., 2009). Based on interviews with those key stakeholders, other relevant stakeholders were invited. In total, 40 personalised invitations were sent out, aiming at approximately ten participants per workshop with a variety of backgrounds. There were many positive responses, as 31 stakeholders initially agreed to participate, five of whom had to cancel last-minute due to unforeseen circumstances. In total, 26 stakeholders participated (see Table 6.1).

A key stakeholder in the workshop on diabetes technology was the Dutch Diabetes Foundation, which represents the interests of diabetes patients in the Netherlands and invests in promising technologies for treating and curing diabetes type 1 and 2. Based on an interview with a (senior) representative of this organization, a representative of a business working on an artificial pancreas for treating diabetes type 1, a representative of a business working on detecting diabetes type 2 at an early stage, and a representative of an organization working on the development of a regenerative therapy for diabetes type 1 were invited. All three technologies are based on nanotechnology. The representative of the Dutch Diabetes foundation, the CEO and business developer of the company working on the artificial pancreas and the CEO of the company working on the early diagnostic device were present at the workshop, but no representative of the organization working on the regenerative medicine was able to come. Additionally, three researchers working on nanotechnology for diabetes applications, a senior policymaker involved in advising the national government for diabetes policies, and a diabetes type 1 patient—who also attended the citizen consultation—were present.

A key stakeholder for the workshop on sensor technologies was a professor of advanced materials at a nanotechnology institute working on improving the diagnostics and treatment of diseases through (bio)-medical nanotechnology applications and who is the representative for health technologies at the sensing programme of this institute. Based on interviews with this professor, a post-doctoral researcher who works on the development of sensors for better detection of cancer through proteins and two researchers from other disciplines (biomedicine and oncology) were invited, as well as a representative of a company working on the detection of cancer through urine. The four researchers from various disciplines and two people from the R&D department of the company were present. Additionally, a social science researcher and a representative of a CSO focusing on responsible innovation and technology assessment were present.

A key stakeholder for the workshop on policymaking was the director of a research institute on nanotechnology. Based on the interview with this stakeholder, a representative of a funding organization, a representative of a business valorisation organization, and a senior policy maker of the Ministry of Health were invited. The director, two programme leaders of a funding organization and a representative of the business valorisation organization were present. The senior policymaker had to cancel at the last minute. Additionally, the national risk coordinator of nanotechnology, one researcher working in the field of nanotechnology, one social scientist, and two citizens who also participated in the citizen consultation were present.

Table 6.1 *Stakeholders present at the three co-creation workshops*

	Product development for diabetes (N)	Research on sensors for cancer detection (N)	Policymaking for nanotechnology in health (N)
Citizen (patient)	1	0	2
Researcher	3	5	2
Business representative	3	2	1
Policymaker	1	0	4
CSO	1	1	0
Total	9	8	9

6.2.3 Specific application areas

Based on the interviews with key stakeholders and the participants who agreed to come to the workshops, application areas and aims for the workshops were identified. One workshop addressed monitoring and diagnostic devices for diabetes patients, focusing on improving product development. The second workshop was about sensor technologies for better detection of cancer, focusing on improving and adjusting the research. The third workshop was about policymaking for nanotechnology and health, focusing on creating a framework for policymaking. The first two workshops were relatively specific: the first workshop was application oriented, addressing a technology in its late developmental stage, and the second workshop was technology oriented, addressing a technology in an early developmental stage. The third workshop was policy oriented and did address a particular nanotechnology application for health.

6.2.4 Procedure

The procedure of the co-creation workshops was based on the four phases of design thinking: exploration, ideation, prototyping, and reflection. These phases foster creativity and promote the integration of different types of knowledge (Tohidi et al., 2006; Yoo et al., 2013).

In the exploration phase, participants introduced themselves, and the specific topic of the co-creation workshop was presented. In the co-creation workshop on diabetes, two representatives from different technological start-ups presented their products. One product was an artificial pancreas, which is a device for diabetes type 1 patients that continuously monitors the blood and automatically injects insulin when needed. The other product was an early diagnostic device that can detect diabetes type 2 at an early stage before any symptoms occur. In the co-creation workshop on sensor technologies, a researcher presented her research on sensors for better detection of cancer through proteins. In the policy-related co-creation workshop, there was no focus on a specific technology or research. Instead, the moderator introduced the question to the participants about how to increase RRI by integrating societal needs and values in product- and research development in nanotechnologies for health.

During the ideation phase, the participants responded to the presentations based on insights from their (personal or professional) background. Then, the moderator introduced the values and needs from the citizen consultation. The participants deliberated in subgroups on how the product suggestions, research line, or policy framework could take into account these values and needs, coming up with ideas for improvement.

In the prototyping phase, the participants selected one idea within subgroups and created a storyboard based on this idea. In this storyboard, various stakeholder perspectives, such as the perspective of the patients, policymakers, researchers, developers, and health professionals, were included. By making such a storyboard, the participants developed their ideas into specific suggestions and included various types of knowledge.

The co-creation workshop ended with the reflection phase, during which the two subgroups presented their ideas to each other. The subgroups were asked to come up together with a plan for follow-up actions based on the presented ideas.

6.2.5 Analysis

The co-creation workshops were analysed based on the experiences of organizing the co-creation workshops, the observations and the recordings of the workshops, the questionnaires that were distributed at the end of each workshop, and the interviews that were conducted after all three workshops. The first two authors of this article organized all co-creation workshops and were present during the workshops. They recorded the workshops and made extensive notes. The recordings and notes provided insights about the dynamics during the workshop.

Furthermore, at the end of each co-creation workshop, an evaluation questionnaire was distributed that included questions regarding the outcomes of the co-creation workshops and the process itself. These provided insights into the participants' perceptions of the workshops. Additionally, after organizing the three co-creation workshops, evaluation interviews were conducted with stakeholders who participated in one of the co-creation workshops. Those interviews were held with a business representative, a researcher, and a CSO representative who participated in the diabetes workshop, a researcher who participated in the sensor workshop, and a policymaker and citizen who participated in the policymaking workshop. The semi-structured interviews included questions about the co-creation process and the outcomes of the workshops and lasted between 30 and 40 minutes and added more insights into the effectiveness of the co-creation process based on the output of the three workshops.

6.3 Results

We first describe the dynamics and outcomes of the three co-creation workshops. After that, we reflect upon the four dimensions of RRI, i.e., reflexivity, inclusion, anticipation, and adaptation, in relation to the three co-creation workshops.

6.3.1 Dynamics in the three co-creation workshops

6.3.1.1 Product development for diabetes patients

In the co-creation workshop on diabetes, suggestions were made for two products. For the artificial pancreas, the participants came up with a data management plan for the use and sharing of data collected with this device. Stakeholders suggested changing the functionality of the artificial pancreas in a way that the user (patient) would get more autonomy by giving him or her the opportunity to decide what would happen with the collected data. They suggested four options for data sharing. One option was to not share any data at all and to keep the analysis of data with the patient. In this way, privacy and security of the data would be safeguarded. Another option was that the data would be directly sent to a health professional, who could inform the patient when an anomaly would be detected. In this way, the patient would not be constantly aware of his or her health data—improving a patient's well-being—and the healthcare professional would be included in the care loop. Another option was to share the date with a caregiver who could monitor the patient's health data. This could be especially useful in the case of patients who are less able to interpret the data themselves and would increase the accessibility of the device. The fourth option was that the data would be sent to the company developing the device, which could improve the device based on big data analysis.

The data management plan represents a number of values and needs that were defined by the citizens in the citizens' consultation. The various stakeholders were all able to contribute to the suggestions for the data management plan, and the results of the questionnaire indicated that the stakeholders were positive about the process of the workshop. Furthermore, the outcome was regarded by the stakeholders as relevant and feasible. However, in the evaluation interview, the business developer of the company working on the artificial pancreas stated that he would not (yet) implement the suggestion in their product. Although he acknowledged the relevance of data management and learned from the workshop that it would be good to integrate a functionality to personalise the data sharing, the company had other priorities.

The subgroup that worked on the early diagnostic device for detecting diabetes type 2 in an early phase suggested an implementation plan. The stakeholders came up with indicators and took into account and gave different options for these indicators. These indicators include defining the target audience of the device, either all people or only high-risk people; deciding upon the place where the device can be implemented, e.g., general practitioner's (GP) office, communal centre or other public places; thinking about the person who operates the device, e.g., a doctor, nurse or volunteer; deciding upon how to motivate people to use the device, e.g., national campaign, information distributed at GP's office, through other health professionals or through peers; and thinking about who should initiate the campaigns and pay for the use of the device, e.g., local health authority, national government, insurance company, citizen themselves.

The stakeholders did not focus on the design and technicalities of the device but on the implementation and use. The different options in the implementation plan reflected different needs and values of the citizens, including affordability and accessibility of healthcare, the need for preventive healthcare, inclusion of the health professional in the care loop and creating awareness of health technologies, and were formulated based on the different perspectives of the stakeholders. For example, the policymaker explained how the organization of a national campaign works and the CSO representative explained how awareness among citizens for diabetes (type 1 and 2) was being created. Additionally, regarding this outcome, the stakeholders indicated that it was relevant and feasible. Furthermore, the CEO of the company that develops that device emphasized that he gained insights into the social context where his product would be implemented, which he had not thought of before. However, he was not planning any specific follow-up action based on this suggestion because the product was still in an early developmental stage.

6.3.1.2 Research development for sensor technology

In the co-creation workshop on sensor technologies, suggestions were made for the development and improvement of a research project on the detection of cancer through proteins. Participants were divided into two subgroups, and both groups had difficulties using the output of the citizen consultation as a starting point. Instead, they addressed several other issues and suggestions based on their professional background and expertise. One group mainly focused on the application of the research and emphasized that the research would be improved by identifying for which types of cancer there is a need for better diagnosis and by talking to healthcare professionals and medical researchers. The other group addressed how the technology itself could be improved by suggesting improving the device by labelling cell-specific proteins through desk research, interviews with other researchers in this field, and empirical research. For the latter step, a plan was made of how to obtain tumour cells for the study and how to obtain access to laboratory equipment.

In this workshop, the stakeholders discussed more technical details of the research and the potential application. By including researchers with different backgrounds and societal actors, specific suggestions for improving the research trajectory and thereby the development of the technology were being made. However, the participants did not connect their suggestions to the outcomes of the citizen consultation, since these outcomes were not technology oriented. Furthermore, not every participant felt he or she could contribute, as the workshop required specific (technical) knowledge. Although most participants thought the workshop was interesting and led to relevant insights, they did not perceive an added value for their own area of expertise. Only the researcher whose research was discussed perceived great added value by the workshop.

6.3.1.3 Policymaking for nanotechnology and health

In the co-creation workshop on policymaking for nanotechnology and health, stakeholders were asked to suggest ideas to stimulate RRI in policymaking on nanotechnologies for health. Two subgroups were formed, and both further developed a particular idea. One idea involved mission-oriented research and innovation, with a specific solution for a societal problem and developing research and innovation from that perspective. The other idea was a field lab where researchers can test their technologies with (potential) users. The mission-oriented research was based on the insight that societal challenges could not be approached by one innovation, but a combination of multiple innovations would be needed. Instead of concentrating on funding and developing research based on one specific innovation or type of research group, the participants suggested defining a clear mission. This would include a restructuring of funding schemes and research groups. The stakeholders did not base the idea of mission-oriented research on specific output of the citizen consultation but emphasized that societal needs and values should be taken into account when defining the mission. Although the stakeholders thought that the idea of mission-oriented research was relevant, they expressed concerns about the feasibility as it required a systematic change in research and innovation and involvement of a wide variety and large number of stakeholders.

Furthermore, the participants of the workshop thought the idea was rather abstract without a plan for follow-up actions.

The idea of the field lab was derived from the stakeholders' observation that many health technologies take a long time to market even though there is a clear need for these technologies in society and that there is a large gap between the technologies being developed in laboratories and wishes and needs in society. In the suggested field lab, novel nanotechnologies can be tested among potential users. The field lab should be situated in a public place (for instance, a hospital) to make sure that everyone has access to the technologies. In addition to collecting input from users (patients, potential patients, health professionals), the field lab could also function as a way of disseminating scientific developments and creating awareness among the general public.

The idea of the field lab was not based on the outcomes of the citizen consultation, but the stakeholders did take the outcomes into account. For instance, the field lab could be used to communicate about novel technologies to citizens, involve them in the development, and better consider the potential implications of nanotechnology. Furthermore, the stakeholders emphasized that the accessibility of the field lab for various publics in society should be ensured. The stakeholders were very positive about the discussion and felt that every stakeholder could add his or her perspective. Furthermore, the stakeholders thought that this idea was relevant and novel, and they were more positive about this outcome than the stakeholders in the other workshops about their outcome. Additionally, in the evaluation interviews, the policymaker expressed her enthusiasm for the idea of the field lab. However, none of the stakeholders took specific follow-up actions after the workshop.

6.3.2 Findings based on the analysis of the co-creation workshops

6.3.2.1 Reflexivity

Reflexivity is important for both a legitimate innovation process and added value to innovation, as it is related to the willingness of scientists and innovators to open up their innovation trajectory to other stakeholder perspectives. With regard to the co-creation workshops, reflexivity refers to the willingness of scientists and innovators and other stakeholders to participate in the workshop and to reflect upon their daily practices related to innovation development. In every co-creation workshop, the participants showed a certain level of reflexivity, as they took the time to participate at the workshops and to reflect upon nanotechnology development for health. However, in the workshops that were connected to a specific innovation and a stakeholder perspective, which was the case in the diabetes workshop and the workshop on sensor technologies, stakeholders showed more reflexivity than their own daily practices than in the workshop without a clear stakeholder perspective.

In the workshop on diabetes, the representatives of the two businesses showed their willingness to reflect upon their innovation by discussing it with other stakeholders. They agreed to present their technology during the workshops and were interested in suggestions. Similarly, in the workshop on sensor technologies, one of the researchers reflected upon her research project. In the workshop on policymaking, various policymakers were present, and they suggested ideas for better integrating societal needs and values in nanotechnology development, but none of them discussed or reflected upon their own daily practices.

6.3.2.2 Inclusion

Inclusion is an important condition for a legitimate innovation process and concerns the engagement of various stakeholders in the innovation trajectory. With regard to the co-creation workshops, inclusion requires an equal distribution of power among the participating stakeholders so that every participant can add value to the innovation based on his or her interests. Based on the analysis of the three co-creation workshops, it became clear that when there was a clear focus on an innovation and/or research, as was the case in the diabetes and sensor workshop, it was difficult to treat all stakeholder perspectives equally. In both co-creation workshops, a clear starting point was chosen, which was introduced from a particular stakeholder perspective—the diabetes technologies from the two businesses and the sensor technology from one of the researchers. This stakeholder perspective led to specific discussions, which made it easy to connect the suggestions to existing technologies, but it came at cost of inclusiveness as it was only relevant for the particular stakeholder rather than the other participants.

In the co-creation workshop on diabetes, for instance, one of the researchers who was present at the co-creation workshop explained in the evaluation interview that for her, the workshop was not very relevant. She develops a technology for detecting biomarkers of diabetes type 2 in blood, but the discussion was mainly about the implementation of a diagnostic device and the data management plan. The CSO representative shared this opinion, stating in the evaluation interview: *"I have the feeling that we indeed created something for the diagnostic device. Stakeholders with different backgrounds were brought together and created new insights. However, this was especially relevant for the CEO of the start-up working on the device and not for myself or my organization"*. Similarly, in the co-creation workshop on sensor technology, the business representatives thought that there was little added value for themselves as the focus of the debate was on the research process. For the post-doc researcher, however, the co-creation process was very relevant, as she obtained various insights for improving her line of research.

In contrast, the co-creation workshop on policy for nanotechnology was not presented from a specific stakeholder perspective and was left open. All stakeholders were free to come up with all ideas and suggestions they thought were relevant, which led to a more inclusive co-creation process. Participants were more positive about the outcome of this workshop. A participating policymaker, for instance, said: *"the workshop on policymaking and nanotechnologies is a good example of co-creation: With all participants we came to the idea of the field lab, which is a great and innovative idea to which every stakeholder contributed"*. A participating citizen concluded: *"It is important to have a mixture of experts and non-experts present in the co-creation process, and everyone should be treated as an equal partner (non-hierarchical). This happened in our co-creation workshop when we jointly developed the idea of a field lab"*. These findings indicate that inclusion is related to the openness of the workshop and that there is a trade-off between inclusion and specificity in the co-creation workshops that were organized.

6.3.2.3 *Anticipation*

The aim of the co-creation workshops was to align nanotechnology development with societal needs and values. This required a certain anticipation of stakeholders towards future applications and implications of the technology and taking into account the societal needs and values that were defined in the citizen consultation. Based on the analysis of the three co-creation workshops, it became clear that anticipation was better possible in the application-oriented co-creation workshop, focusing on a later stage of technology development, than in the technology-oriented workshop, focusing on the early stage of technology development. The former was the case in diabetes, and the latter was the case in the workshop on sensor technologies. Furthermore, in the co-creation workshop without a specific orientation, as was the case in the workshop on policymaking, it was also possible to anticipate societal needs, as the participants brought in the application perspective during the workshop.

In the co-creation workshop on diabetes technology, stakeholders were able to anticipate various societal needs and values, which were defined during the citizen consultation. These values and needs could be easily connected to the products as they were application- and user-oriented. In fact, these needs and values served as a base for the suggestions from the stakeholders during the workshop. It appeared to be much harder to connect the outcomes in the co-creation workshop on research development for sensor technologies to needs and values as defined in the citizen consultation. In this context, deliberating the technology and research required specific technical knowledge, and participants who were not experts in the field of nanotechnology found it difficult to contribute to the debate. Furthermore, the suggestions were not connected to the citizen consultation, as they were not considered relevant for the early developmental stage of the technology. One of the researchers stated, for example, in the evaluation interview: *"I don't see any added value of including citizens in this co-creation process as the deliberation on the research project requires specific and technical knowledge. It is more relevant to include potential users of the technology in the discussion, who are in this case health professionals"*. In the workshop on policymaking, the stakeholders were also able to anticipate their suggestions based on societal needs and values, as they brought up the application-oriented perspective during the workshop. They did not use the needs and values as the starting point but took them into account when discussing how to apply the field lab in society. In this discussion, the perspective of the citizens, i.e., their needs and values was one of the perspectives that was included. These findings indicate that anticipating societal needs and values is possible in workshops with an application-oriented perspective, often in a later stage of innovation.

6.3.2.4 *Adaptation*

The creation of added value to nanotechnologies requires the action of stakeholders along the value chain to adjust innovation (trajectory) based on societal needs and values, which is referred to as adaptation. Adaptation in the context of this research is the intentional or actual adjustment of research, product development, or policymaking by one or more stakeholders based on the outcomes of the co-creation workshops. The analysis of the three co-creation workshops showed that adaptation could be achieved if there was a problem owner among the stakeholders who felt responsible for the specific topic—technology and/or question—discussed in the workshop, as was the case in the senor workshop. When none of the stakeholders felt responsible, which was the case in the diabetes and policymaking workshop, there was little intention among the stakeholders for follow-up actions. However, the three co-creation workshops did not start from a problem-oriented perspective, but the themes were decided based on interviews with experts, and the outcomes of the citizen consultation and the stakeholders were identified based on the themes, which made it difficult to find a problem-owner for each of the workshops.

For the co-creation workshop on diabetes, for instance, the question of the workshop was left relatively open, i.e., how can product development be improved based on societal needs and values? Although the outcomes were relevant for the business representatives, they did not (yet) implement the results of the co-creation workshop in their product development or had specific intentions for follow-up actions. The CEO of the company working on the early diagnostic device stated that their product was in the (early) developmental stage, and he did not (yet) see added value of integrating the implementation plan in the innovation process. The representatives of the company working on the artificial pancreas explained that they were about to get the certification for the artificial pancreas, and they did not want to change the functionality of the product at this stage. They thought it would have been more useful if the workshop focused on specific problems they encountered in the innovation process. One of the business representatives explained: *"In the development of our technology, we are dealing with very specific problems, and I had the feeling that the co-creation activity was too general for that. The workshop would have been more useful if it would have been centred around our specific issues and challenges"*. After the co-creation workshop on research development for sensor technologies, the researcher took follow-up actions based on the outcomes of the workshop. The participants of the workshop suggested how to improve the researcher's research, and as such, the research project was the main focus of the workshop and not the societal needs and values. Based on these suggestions, the researcher adjusted her research project, and she concluded: *"The co-creation workshop was a game-changer for me. The insights that were given by the different stakeholders pointed out relevant issues to take into account and raised relevant questions about potential applications and user groups. I integrated all these insights in my research"*. In the workshop on policy making, the theme was left open, and there was no stakeholder perspective connected to the workshop, which made adaptation even more difficult than in the diabetes workshops. Although all participants were positive about the idea of the field lab, there was no stakeholder who felt responsible for it and took any follow-up actions after the workshop. A policymaker who was present at that workshop explained in the evaluation interview: *"Everyone was enthusiastic about the idea of the field lab. However, the roles of the different participants were not specified, and no further action was taken. It would be good to specify these roles during the co-creation workshop and define steps for valorisation and implementation"*. These findings indicate that adaptation requires a sense of problem ownership among the participating stakeholders, which can be easier achieved in a workshop that includes a stakeholder perspective and focuses on a specific problem or challenge.

6.4 Discussion

6.4.1 Main Findings

The experiences in the three workshops suggest that there are several challenges related to reflexivity, inclusion, anticipation and adaptation when setting up co-creation in support of RRI (see Table 6.2). The diabetes workshop was reflexive, as there was a clear innovator's perspective included. Furthermore, it was easy to anticipate potential impacts of the discussed products because the workshop was application oriented and stakeholders discussed the implementation and use of the products. However, the workshop was only partly inclusive because the workshop was presented from a specific stakeholder perspective. Furthermore, adaptation played no role based on the outcomes of the workshop, as none of the stakeholders took any follow-up actions or intended to use the outcomes in the further development of the products. Therefore, it can be concluded that this workshop was partly legitimate and led to little added value of the innovation.

The outcomes of the workshop on research on sensor technologies for detecting cancer were reflexive but did not include any societal needs and values because it was difficult to anticipate the potential impacts in a technology-oriented workshop. Additionally, this workshop was not very inclusive: mainly researchers were present at the workshop, and those were the only actors who were able to substantially contribute to the research development. Furthermore, due to the specific stakeholder perspective, the workshop was most relevant for one particular researcher and less relevant for the other stakeholders. This researcher adapted the research trajectory based on the outcomes of the co-creation workshop. Thus, this workshop created added value to the innovation but did not lead to a legitimate innovation trajectory.

The workshop on policymaking for nanotechnologies was only partly reflexive since stakeholders reflected upon policy making in general, but none of the stakeholders included reflection upon their daily practices. The workshop was inclusive because all stakeholders operated on the same level due the open character of the workshop. They were all equally responsible for the outcome of this workshop. Additionally, the outcomes anticipated societal needs and values. However, none of the stakeholders took further action after the co-creation workshop. Therefore, this workshop can be considered legitimate, but no added value of the innovation was created.

Table 6.2 *Characteristics of the three co-creation workshops*

	Reflexivity	Inclusion	Anticipation	Adaptation	Result
Diabetes product development	Reflexive	Partly inclusive	Anticipative	Not adaptive	**Partly legitimate / partly added value**
Research sensor technologies	Reflexive	Not inclusive	Not anticipative	Adaptive	**Added value**
Policymaking for nanotechnol-ogies	Partly reflexive	Inclusive	Anticipative	Not adaptive	**Legitimate**

Co-creation to foster RRI aims for both a legitimate innovation trajectory and added value to the innovation. In theory, both Von Schomberg (2012), in his definition of RRI, and Voorberg et al. (2015), in their definition of co-creation, emphasized that there is a need for mutual responsibility or collaboration to create a legitimate innovation process and created added value to the innovation or product. However, in practice, we found that it is difficult to create this responsibility, and there is a trade-off between both aims. To add value to the innovation itself, there is a need for a certain level of adaptation, which can be achieved through specificity, in terms of focusing on a specific technology or product, and by having a clear action-oriented perspective. The latter can be gained by connecting the subject of the co-creation workshop to the work of a particular stakeholder. However, this comes at the cost of inclusion, which is needed for a legitimate innovation trajectory, because it gives the stakeholder a certain power over the other stakeholders. Earlier research has already concluded that an inclusive and adaptive innovation process inevitably leads to the question of power (Jarmai & Vogel-Pöschl, 2020; Stilgoe et al., 2013). There are always agencies that initiate and facilitate co-creation, and there is action needed from relevant actors for taking up the outcomes of the co-creation activity. This predefined ownership might influence the distribution of power and thereby negatively influence the collaboration between stakeholders in the cocreation process (Jarmai & Vogel-Pöschl, 2020).

Furthermore, we found that adaptation is easier to achieve in an early developmental stage of the technology, as there is still room for adjustment than in a later stage, and anticipating societal needs values is easier in an application-oriented workshop. This finding is in line with the Collingridge dilemma or the dilemma of control, meaning that at the start of the innovation process, there is often insufficient knowledge about the trajectory and the implications of the innovation, but the innovation can be easily adjusted. At a later stage of innovation, impacts can be more easily predicted, but it is more difficult to adjust innovation, often due to limited resources (e.g., Genus & Stirling, 2018; Owen et al., 2012).

6.4.2 Theoretical contributions

Our findings align with the conclusions of Delgado et al. (2011), who detected a gap between theory and practice of public engagement based on various tensions. The most fundamental tension they found was related to rationales or aims of public engagement, which they described as instrumental, substantive or normative. Public engagement exercises with an instrumental rationale aim to achieve a particular predefined end, a substantive rationale focuses on innovation development, and a normative rationale implies that public engagement will lead to increased legitimacy. The authors emphasized that tensions between the rationales particularly arise when exercises have been theoretically argued for according to one rationale (e.g., substantive) but then were designed, enacted and/or evaluated according to another (e.g., normative) (Delgado et al., 2011). Stirling (2008) found that the tensions between the normative and substantial rationale are closely related to democratic openness and technocratic closure. An open co-creation process in which various stakeholders have an equal say is inclusive and therefore legitimate (normative aim) but does not necessarily lead to adaptation of the innovation (substantive aim). Indeed, our findings indicate that, in theory, co-creation as a means for RRI is based on a normative and substantive rationale, but in practice, it is difficult to achieve both aims as there is a trade-off between inclusion and anticipation—related to democratic openness—and adaptation— related to technocratic closure—. It may seem tempting to focus mainly on technological closure for the sake of innovation development, but some scholars (e.g., Jasanoff, 2014; Rowe & Frewer, 2005; Wynne, 2006) argued that this technological closure should not become a goal in itself. This would lead to an instrumental objective of co-creation and could be a lost opportunity for including different perspectives in the development of the innovation, thereby overlooking societal needs and values. However, solely focusing on the inclusion of these different perspectives might be a lost opportunity as well. It requires a pro-active approach of stakeholders to adapt the innovation process (Foley et al., 2016), for which a sense of ownership is required.

Instead of trying to integrate all rationales in the co-creation for RRI, it would be better to acknowledge that co-creation can come in different forms. Based on previous literature and our findings, we can distinguish three different types of co-creation: co-creation as a tool for including different types of audiences in the innovation process (as referred to by Polk, 2005); co-creation as a tool for anticipating societal needs and values in the innovation trajectory (as referred to by, for instance, Gudowsky and Sotoudeh, 2017; Mauser et al., 2013); and co-creation for adapting the innovation based on suggestions from different types of publics as a tool for innovation development (as referred to by, for instance, Van de Grift et al., 2020; Von Hippel, 2005). There is not one type of co-creation better than the other because RRI includes various dimensions, including reflexivity, inclusion, anticipation, and responsiveness that each touch upon the different types of co-creation. However, it is important to predefine the aim of the co-creation event, to be transparent about this aim when organizing the event, and to take into account the design of the workshop that suits this aim.

6.4.3 Limitations and suggestions for future research

This research, however, does have some limitations. An important limitation is that the findings of our study are based on an analysis of only three co-creation workshops. This qualitative methodology provided us with the opportunity for an in-depth analysis and evaluation of the effects of the different characteristics of the co-creation workshops on the various dimensions of RRI. However, we should take this small number into account when generalizing and interpreting the results. For future research, it would be interesting to study multiple co-creation configurations based on the outcomes of this study, thereby providing a more systematic analysis.

Second, the setup of the cocreation workshops was based on the methodology designed within the H2020-project GoNano, and there was no clear problem as a starting point for the cocreation sessions. Instead, the themes and application areas were selected based on expert interviews, the outcomes of the citizen consultation, interviews with key stakeholders, and the stakeholders who were able and willing to participate in the co-creation workshops. This influenced the outcomes and follow-up actions of the workshop, as described in the results section. It will be interesting to study a problem-oriented co-creation session in future research, in which a specific problem or challenge of a stakeholder is used as the starting point and stakeholders connected to this problem are being invited to the workshop.

Third, not every co-creation workshop involved the same type of stakeholders. In the co-creation workshop on sensor technologies, no citizens or policymakers were present, and in the workshop on policymaking for nanotechnology and health, there was not a representative of a CSO present. Although the aim was to come to a mixture of different stakeholders per session based on a normative stakeholder approach, there were some stakeholders who cancelled last-minute.

6.4.4 Conclusion

This study contributes to insights into co-creation as a tool for responsible research and innovation. Co-creation comes in different forms and shapes. The concept refers to a participative process where different types of publics together generate meaning and value, but the design of this participative process, the types of publics, and the stage of the innovation differ. In theory, co-creation aims for the creation of meaning through the participative process, which can be referred to as the creation of a legitimate innovation process, and the creation of value based on the outcomes, which we label as the added value of the innovation. In this study, we have shown that the design of the co-creation methodology in terms of openness and specificity, developmental stage, and the presence or absence of a stakeholder- and action-oriented perspective influences the RRI dimensions of reflexivity, inclusion, anticipation and adaptation. Based on those dimensions, a trade-off can be detected between the two aims of creating legitimacy and creating added value. Instead of integrating both aims when setting up a co-creation workshop in support of RRI, it would be wise to focus on a specific aim.

7

General discussion

7.1 Main findings

Present-day societies are facing grand societal challenges, and various technological innovations that are being developed might contribute to the solution. However, the successful development and implementation of these technological solutions are not always accomplished, as such innovations require the involvement of different stakeholders who have their own interests in, stakes in, and perceptions of the desirability of technological change (Köhler et al., 2019; Kuhlmann & Rip, 2014; Von Schomberg, 2014). Therefore, communication with involved parties or, more specifically, stakeholder interactions, plays an important role in the innovation process (e.g., Bergek, Jacobbson & Carlosson et al., 2008; Geels & Schot, 2007; Leeuwis & Aarts, 2011). To gain a deeper understanding of the role of communication in the innovation process, this dissertation analyses how stakeholder interactions affect the development and implementation of innovations and thereby facilitate or hinder technological change. These interactions are approached by applying concepts from three different disciplines, including science and technology studies (STS), communication science, and science communication. Based on these concepts, two objectives for this dissertation were formulated:

1. Create an overview of the stakeholder interactions that influence the development and implementation of technological innovations;
2. Gain a better understanding of how stakeholder interactions can support legitimacy and contribute to socially robust innovations.

To meet these two objectives, five empirical studies were conducted, each addressing one or both objectives. Below, the main results of the studies are summarized.

Chapter 2 reports on an analysis of the stakeholder interactions that are needed for the development and implementation of technological innovations. These interactions were approached from an entrepreneurial perspective based on interviews with 24 CEOs and/or founders of technological start-ups working on innovations in the healthcare, sustainability, safety, high-tech systems and materials (HTSM) and ICT domains. This chapter shows that the entrepreneurs mentioned a wide diversity of interactional processes. These interactions are partly related to communication about the technology with the aim to create a positive perception. These interactions include framing and explaining the technology, creating media attention and lobbying, and they support these functions: legitimation, resource mobilisation, and market formation. The other interactions aim to improve the innovation by including stakeholders' needs and values in the innovation process. These interactions include collaborating with other parties, sharing knowledge, getting advice, strategically choosing the application and sector, and adapting to the social environment. They support these functions: legitimation, resource mobilisation, market formation, knowledge development, and entrepreneurial experimentation. The entrepreneurs indicated that both types of interactions are needed throughout the entire innovation process. The study shows that the functional approach of the TIS framework, as developed by Hekkert et al. (2007) and Bergek, Jacobsson, Carlsson et al. (2008), can be used at an actor level and helps to understand the purpose of stakeholder interactions. It contributes to the innovation literature by providing an overview of the interactions that are needed to address the various functions of TIS, which has not yet been done. As such, this study contributes to the first objective of this dissertation.

Chapter 3 describes a media analysis focusing on the technology legitimation of genetically modified (GM) food in the public discourse. The creation of legitimacy is one of the core functions of the TIS framework and the MLP framework and is therefore an important precondition for facilitating technological change. This study explores how the four pillars formulated by Binz et al. (2016) can serve as an analytical framework to study technology legitimation in the public sphere. The four pillars consist of a cognitive, a normative, a pragmatic, and a regulative pillar, each of which reflects a different dimension of legitimacy. The media analysis shows that the pillars can indeed be used as a generic framework to study the state of technology legitimacy in the public discourse. It demonstrates the importance of considering all four pillars when addressing legitimacy. Furthermore, the framework gives insights into the dynamics within each pillar in terms of sentiment and arguments and the differences and similarities between pillars. In the debate on GM food, the normative pillar—judgements about whether the technology is right for society—was dominant, followed by the cognitive pillar, which is knowledge and understanding of the technology. Both were addressed in a predominantly negative way. Furthermore, in the normative pillar, relatively few arguments were given, which indicates that emotional and irrational factors were prevalent in this pillar. The regulative pillar, which is the alignment of the technology with laws and regulations, and the pragmatic pillar, which is judgements about the utility of technology, were less often addressed, and only the pragmatic pillar was predominantly addressed in a positive way. This study contributes to the second objective of this dissertation because it enhances our understanding of technology legitimacy and provides insights into the relevance of addressing all four pillars of legitimacy in the public discourse.

Chapter 4 describes a mixed-method study on the perceptions of homeowners and tenants regarding the transition towards sustainable heat in the Netherlands. The aim was to investigate the antecedents of resident attitudes towards the transition to function as input for a communication strategy to get them on board. In contrast to the two previous studies, this study does not address a single technological innovation but studies the perception of technological change, i.e., becoming natural gas-free, which encompasses multiple sustainable heating innovations. The analysis shows that although the perceived role of homeowners and tenants with regard to the implementation of the transition differs, they considered similar themes to be important in the transition. The study reveals that both groups showed an interest in the transition; they wished to have the opportunity to engage in the process and considered similar characteristics of the sustainable technologies important when choosing an alternative for natural gas. Furthermore, similar antecedents—environmental concerns and trust in responsible actors—mattered for both homeowner and the tenant attitudes towards becoming natural gas-free. Interestingly, the homeowners and tenants had a higher trust in actors that were close to them, such as a civil neighbourhood council. This study contributes to the first and second objective of this dissertation, showing that it is important to offer the possibility for participation, to communicate about the societal challenge that needs to be addressed and the consequences of the innovation(s) and to take the perceived trust of the relevant stakeholders into account when facilitating acceptance among (potential) end-users of sustainable technologies.

Chapter 5 describes the potential of engaging citizens in the development of nanotechnologies for health based on extensive focus groups. This chapter analyses to what extent citizens can contribute to socially robust innovations and which values are reflected in their contributions. The study illustrates that citizens are able to contribute to a broad range of technology aspects, including implementation, use, system, development, design, and communication. Most suggestions were given for the circumstances and conditions (implementation aspect) under which they were willing to use the technologies (use aspect), concentrating on the user perspective. Furthermore, citizens made suggestions for the embeddedness of the technologies in the system and the development of the technologies centred on a societal perspective. Their suggestions were derived from concerns about the potential effects of the technologies and were mainly based on the values of well-being, autonomy, and privacy. The importance of these values differed by technology aspect; for instance, well-being was considered especially important when discussing the use of technologies, while autonomy and affordability were important when discussing implementation. This study contributes to the second objective of this dissertation, demonstrating that citizens are a relevant and valuable stakeholder group to engage in the development of technological innovations. Based on citizen suggestions, innovations can be developed in a more socially robust way.

Chapter 6 describes how co-creation with different stakeholders, including researchers, businesses, policymakers, civil society organizations, and citizens, can support the RRI of nanotechnologies for health based on an analysis of three co-creation workshops. Co-creation is defined as a form of engagement in which stakeholders jointly generate meaning and value with the aim of enhancing legitimacy and/or adding value to the innovation. These aims are closely connected to RRI, which emphasises the need for a democratic innovation process and socially robust innovations based on four dimensions: reflexivity, inclusion, anticipation, and adaptation. The analysis indicates that it is difficult to address all four dimensions at the same time. Reflexivity and adaptation require a specific stakeholder and action-oriented perspective, which comes at the cost of inclusion. Furthermore, it is easier to adapt an innovation that is early in its development process, but at the same time, this increases the difficulty of anticipating (potential) impacts. Consequently, a trade-off between legitimacy and added value was uncovered. A co-creation process focusing on added value requires deliberation early in the innovation process, a certain specificity and an action-oriented perspective. However, this might decrease legitimacy, as it is less inclusive and less anticipative. This study contributes to the second objective of this dissertation, showing that co-creation can be a useful interactional process to support the creation of legitimacy or to develop socially robust innovations. However, it should be acknowledged that co-creation comes in different forms, and when setting up co-creation sessions, the design should fit the predefined aim and be communicated to the stakeholders involved.

7.2 Theoretical implications

This dissertation aimed to provide a better understanding of how stakeholder interactions facilitate technological change by addressing the two objectives described above. Below, the theoretical implications of the empirical studies for both objectives are discussed.

7.2.1 Stakeholder interactions and technological innovations

The first aim of this dissertation was to provide an overview of the stakeholder interactions that affect the development and implementation of innovations. In the innovation literature, the TIS framework and the MLP framework provided a better understanding of the complexity of the innovation process and the dynamics of technological change. The TIS framework explains how emerging technologies are developed and influenced by actors interacting with each other in formal and informal networks shaped by institutions (norms and regulations). These stakeholder interactions have various functions that are needed for technology development (Bergek, Jacobbsson, Carlsson et al., 2008; Hekkert et al., 2007). The MLP framework provides a better understanding of technological change and transitions in society. It addresses how new, radical innovations are being developed and implemented and the efforts that are needed to give these innovations a chance against existing (competing) technologies that are already being used in society (Geels & Schot, 2007). Both the TIS and the MLP framework have proven their relevance in identifying the potential for creating technological change (e.g., Geels et al., 2018; Jacobsson & Bergek, 2011; Köhler et al., 2019). However, both frameworks have been mostly applied top-down on a system level, addressing a holistic perspective on innovation development, thereby lacking the specific stakeholder perspectives, interactions and strategies that can affect technological change (Geels & Schot, 2007; Markard & Truffer, 2008a, 2008b; Planko et al., 2016; Smink, 2015). This dissertation extends these frameworks by approaching technological innovations bottom-up from a particular stakeholder's perspective. By applying such an approach, insights are gained into how these stakeholders perceive technological innovations and how they can affect the development and implementation of technological innovations through their interactions.

Based on the findings of Chapters 2 and 4, an overview of nine interactions can be made: 1) sharing knowledge and information about the technology, 2) explaining personal and societal consequences of the technology, 3) framing the technology differently when different stakeholders are involved, 4) lobbying, 5) networking, 6) collaborating with other stakeholders, 7) strategically choosing the application and the sector, 8) adapting to the (social) environment, and 9) engaging with relevant stakeholders in the development and implementation of the innovation. These interactions can be categorized into processes that serve a *window-out* function and processes that serve a *window-in* function. The window-out function relates to communication about the innovation to other stakeholders, such as providing information about the innovation, framing, networking and lobbying. These interactions are mainly conducted to create a positive perception about the innovation that aims to promote legitimacy, which is an important precondition for resource mobilisation and market formation. The processes that serve a window-in function focus on the inclusion of different stakeholders' needs and values in the development and implementation of innovations and include four main interactions: collaborating with other stakeholders, stakeholder engagement, strategically choosing the application and sector, and adapting to the social environment. These interactions aim to add value to the innovation, thereby creating socially robust innovations that support knowledge development, resource mobilisation, entrepreneurial experimentation, market formation, and the legitimacy of the innovation.

Leeuwis and Aarts (2011; 2016) theoretically argued the importance of communication throughout the innovation process. In line with this conclusion, the empirical studies of this dissertation illustrate that stakeholder interactions affect the entire innovation process from the (early) developmental phases (Chapter 2) to the implementation phase (Chapter 2 and 4). Furthermore, the window-in interactions (e.g., collaboration between stakeholders or being flexible towards the environment) reflect the nonlinearity of technology development. This nonlinearity has been emphasised from the sociotechnical perspective, assuming that the development of a technological innovation is not necessarily based on technical possibilities and R&D capabilities or on user needs (e.g., Greenacre et al., 2012; Smith, 2008). Instead, an innovation can be developed in various directions and/or have various applications that might be altered throughout the innovation process based on the creation of legitimacy, attraction of financial resources and adoption by (potential) end-users.

Key to understanding the functions of these interactions is the recognition that no single stakeholder is responsible for or able to conduct and control the process of the development, implementation and utilisation of an innovation. In contrast, various stakeholders along the value chain together influence technological change. These stakeholders all affect the development and implementation of technological innovations based on their own perceptions and interests. This dissertation shows that these perceptions can be influenced by other stakeholders, and as such, technological change can be (partly) orchestrated in pre-planned directions. For instance, entrepreneurs can enhance legitimacy among policymakers by emphasising the societal problems their innovation might solve and trying to be part of committees that set regulations and standards for technologies (Chapter 2). They can enhance the mobilisation of financial resources in terms of investment or subsidies by strategically choosing the application of their technology. Additionally, policymakers can enhance the acceptance of the transition towards sustainable heat among residents by emphasising how the transition can help combat climate change and by working on their trustworthiness (Chapter 4).

Finally, two types of stakeholder approaches have been distinguished in the literature to identify relevant stakeholders in the innovation process. First, the normative approach addresses the inclusion of stakeholders who might be affected by the innovation and thereby have a legitimate claim in the innovation process. Second, the instrumental approach focuses on stakeholders who need to be included for the survival of the innovation because they affect the development and implementation of the innovation. As such, they have a certain power over the innovation process (Reed et al., 2009). This dissertation indicates that it is difficult to differentiate between a normative and an instrumental approach because the creation of

legitimacy is one of the key functions that assists the other (instrumental) functions needed for the development and implementation of innovations. Stakeholders who might not have direct power in the innovation process can affect this process through their influence on legitimation. GM food, for instance, faces various challenges in its implementation phase because it lacks legitimacy in the public sphere. Instead of distinguishing stakeholders based on normative and instrumental characteristics, it would be more useful to categorize them based on their perceptions of the innovation. This could help to identify stakeholders in favour of and against the innovation and provide insights into (potential) challenges and opportunities in the innovation process.

7.2.2 Stakeholder interactions contributing to legitimacy and socially robust innovations

The second aim of this dissertation is to create a better understanding of how stakeholder interactions can support legitimacy and contribute to socially robust innovations. Various scholars have recognized the importance of legitimacy for the successful development and implementation of innovations (e.g., Bergek, Jacobsson, & Sandén, 2008; Binz et al., 2016; Geels & Verhees, 2011; Smink, 2015; Tosun & Schaub, 2017). The results discussed in this dissertation confirm that legitimacy is one of the key outcomes of stakeholder interactions. Legitimacy refers to the innovation being perceived as appropriate and desirable by stakeholders and in line with social norms, standards and regulations. In the innovation literature, scholars have studied how stakeholder interactions can support the creation of legitimacy of technological innovations (e.g., Binz et al., 2016; Geels & Verhees, 2011; Groves, 2011; Rempel et al., 2018; Smink, 2015). As mentioned above, these interactions can be divided into interactions that serve a window-out function and interactions that serve a window-in function. The former includes interactions such as framing the innovation in line with norms and values that positively influence collective sense-making (Geels & Verhees, 2011; Petkova et al., 2013; Tosun & Schaub, 2017; Smink, 2015) and lobbying and advocacy work to align standards and regulations with the innovation (e.g., Binz et al., 2016; Tosun & Schaub, 2017). Furthermore, public engagement to build and/or restore trust in technological innovations and their governance can be regarded as window-out interactions that aim for legitimacy as well (e.g., Groves, 2011; Kyllönen, 2012; Rempel et al., 2018). Another way to increase legitimacy is to align the innovation with norms and beliefs, that is, by creating socially robust innovations through public and stakeholder engagement (Groves, 2011; Rempel et al., 2018; Von Schomberg, 2014). This type of engagement serves as a window-in function. Although related work often addresses window-in or window-out interactions separately and only focuses on one type of interaction in the creation of legitimacy, this dissertation takes both into account for the creation of legitimacy.

In line with the literature, this dissertation illustrates that legitimacy could be approached as a multidimensional concept. Binz et al. (2016) proposed four pillars of legitimacy—cognitive, normative, regulative, and pragmatic—as a framework for technology legitimacy, and each pillar reflects a different dimension of legitimacy. They argued in correspondence with other scholars (e.g., Bergek, Jacobsson, & Sandén, 2008; Geels & Verhees, 2011) that each pillar is related to specific stakeholders. The cognitive and normative pillars are related to the creation of legitimacy in the public sphere; the regulative pillar is related to the creation of legitimacy among policymakers; and the pragmatic pillar reflects the creation of legitimacy among end-users or consumers. Extending previous research, this dissertation illustrates that in the public sphere, all pillars matter (Chapter 3), implying that stakeholders should not approach the pillars in isolation but take into account all dimensions of legitimacy when studying or aiming for technology legitimacy. This conclusion is supported by the findings of Chapter 4, showing that end-users consider the effects of sustainable heating technologies important not only for their personal lives (pragmatic pillar) but also for society as a whole (normative pillar). These findings imply that when proponents of an innovation aim for the creation of legitimacy, they should address all four pillars of legitimacy in their communication strategy directed at different types of stakeholders.

Furthermore, this dissertation shows the relevance of engaging with various stakeholders in the different phases of the innovation process of technological innovations. In the literature on public engagement, most research addresses the why and how of stakeholder engagement (e.g., Delgado et al., 2011; Dijkstra & Critchley, 2016; Rip, 2014; Wickson et al., 2010). However, little attention has been given to understanding the outcomes of these initiatives for the development and implementation of technological innovations (Jasanoff, 2014; Shelley-Egan et al., 2018). To close this gap, this dissertation provides in-depth insights into stakeholders' contributions and perceptions. Chapter 5 illustrates that citizens are capable of contributing to the (early) development of nanotechnologies for health by providing suggestions for various technology aspects. Furthermore, in the transition towards sustainable heat, both homeowners and tenants showed interest in the transition and expressed a desire to have the opportunity to participate in the implementation process of sustainable technologies (Chapter 4). Similarly, the results from the co-creation workshops that involved different types of stakeholders (researchers, policymakers, CSOs, businesses and citizens) underlined the relevance of collaborating with multiple stakeholders in the development and implementation of technological innovations (Chapter 6). Based on the empirical studies in this dissertation, it has become clear that different stakeholders bring their own perspectives and can articulate their needs and values well—an important prerequisite for successful engagement and collaboration. In particular, deliberation is possible on the (potential) applications of technologies, which are approached by stakeholders from both a user and a societal perspective. The former perspective includes conditions for use, implementation and development, and the latter connects technologies to the system and the societal challenge(s) they address.

Finally, this dissertation shows how stakeholder collaboration can lead to more socially robust innovations. First, it shows that citizens can substantially contribute to the development of technological innovations (Chapter 5). They are able to relate well to various technology aspects of an innovation in an early developmental stage and provide valuable suggestions based on their values and needs. Second, this dissertation provides insights into co-creation, a form of collaboration in which stakeholders jointly generate meaning and value (Chapter 6).

Co-creation has increasingly received attention as a way of creating socially robust innovations (e.g., Gudowsky & Peissl, 2016; Gudowsky & Sotoudeh, 2017; Mauser et al., 2013; Polk, 2015; Voorberg et al., 2015). Furthermore, it has been proposed as an instrument for responsible research and innovation (RRI) that accounts for a legitimate innovation process and adds value to the innovation (European Commission, 2016; Voorberg et al., 2015). However, this dissertation shows that it is difficult to address both a legitimate innovation process and the creation of socially robust innovations at the same time. There is a trade-off between inclusiveness and anticipation—related to a legitimate innovation process—and adaptation, which is related to adding (social) value to the innovation. As such, this dissertation shows that co-creation can be a useful method to enhance the legitimacy of the innovation process and to contribute to socially robust innovations, but not at the same time. Co-creation can be applied as a tool for including different types of audiences in the innovation process, anticipating societal needs and values in the innovation trajectory, and adapting the innovation based on suggestions from different types of stakeholders.

7.3 Limitations and future research

In the previous chapters, the limitations of each individual study were discussed. In this chapter, general limitations of this dissertation are addressed.

First, in this dissertation, different technological innovations, stakeholder perspectives and research methods are included. A variety of technological innovations were studied, ranging from sustainable heating technologies to nanotechnologies for health and GM food. The stakeholder interactions and perceptions related to these technologies have been studied by means of interviews, media analysis, focus groups, a survey study, and a comparison of co-creation workshops. This broad approach provided the opportunity to examine the emergence and importance of stakeholder interactions, to analyse various stakeholder perceptions towards innovations and to reflect on the role of communication in the innovation process in various contexts. However, the broad approach made it more difficult to compare the interactions between stakeholders and to determine whether the outcomes of the studies were influenced by the innovation under study, the stakeholder perspective addressed, or the research method used.

For instance, in the extensive focus groups on nanotechnology applications for healthcare in Chapter 5, citizens were able to give specific suggestions for the conditions under which they would want to make use of the innovations. It might have been more difficult for citizens to come up with suggestions for technologies they regarded as more controversial, such as nanotechnology applications for food. Food technologies are generally perceived as riskier and more controversial than health or sustainable technologies (Capon et al., 2015). In addition, the stakeholder perspective connected to the study may have influenced the outcomes of the interactions. In Chapter 2, it was found that resource mobilisation and legitimation were most frequently addressed by the entrepreneurs. For researchers, for example, a different function, such as knowledge development, may have been most important. Likewise, the different methods led to different types of outcomes. Based on the media analysis on GM food, an overview could be made of the pillars of legitimacy that were addressed in the public discourse, including the dynamics in terms of sentiment and arguments. However, the public discourse cannot be linked one-on-one to public attitude, which can be studied by means of a survey. For future research, it would be interesting to study the stakeholder interactions that are connected to a specific application area, such as the development of nanotechnologies for health applications. The various perspectives of stakeholders involved in this area could be studied and compared. The outcomes of this dissertation can be used as a starting point and contain the pillars of legitimacy, the window-out and window-in interactions, and the processes of creating legitimacy and socially robust innovations.

Second, although this dissertation addressed relevant stakeholder interactions, it did not study the interaction processes between stakeholders in detail. As such, this dissertation did not address in-depth how stakeholders create meaning based on their interactions. For future research, it would be interesting to study sense-making by means of conversational analysis or observations. These analyses will be relevant, as they provide a better understanding of everyday conversations and interactions and how they influence stakeholder perceptions of technological innovations (Leeuwis & Aarts, 2011). It would be particularly interesting to compare window-out and window-in interactions and the relationship between them.

7.4 Practical implications

This dissertation offers insights into the interactions needed for facilitating technological change. Based on the findings, recommendations can be given for the different types of stakeholders, including researchers, policymakers, and entrepreneurs, involved in the development and implementation of technological innovations.

Researchers can benefit from the results of this dissertation because they need to act within the complex dynamics of technology development (Jacobsson et al., 2014). They can have different roles in the innovation process, such as change agent, knowledge broker, reflective scientist and process facilitator (Wittmayer & Schäpke, 2014). Consequently, researchers could benefit by addressing both window-out and window-in interactions. This dissertation shows that window-out interactions, such as framing and explaining the technology, approaching the media, networking, and lobbying, are useful for researchers to positively influence the perception of the research project or innovation and to create or enhance legitimacy and resource mobilisation. When designing their communication strategy for these interactions, researchers could explain the possible applications of their research from user and societal perspectives rather than from solely a technical perspective. Furthermore, window-in interactions are relevant to increase the social robustness of the research. This enhances the chance of developing their research into a commercialized product that is perceived as legitimate by stakeholders.

Policymakers may realize that they are an important actor for the implementation of technological innovations that might address societal challenges. They could identify relevant stakeholders who can affect or might be affected by the innovation based on the instrumental and normative stakeholder approach and take into account the interests, motives and perceptions of these different stakeholders in the development and implementation of technological innovations. Based on these perceptions, policymakers can develop a communication strategy for citizens and end-users that aims at enhancing the legitimacy of technological innovations and the technological change in society that arises from these innovations. The pillars of legitimacy provide a useful framework to analyse the state of technology legitimacy in the public discourse, which can be used as input for the communication strategy. In this strategy, it is important for policymakers to address the effects of the innovation on potential users and society by explaining how the innovation can change the incumbent system and how it can function as a solution to the societal challenge. Furthermore, based on the perceptions of stakeholders, the innovation process can be adjusted and shaped to increase the desirability of technological change. Co-creation, in which stakeholders generate meaning and value together, can be used as a method to collect stakeholder perceptions and integrate them in innovation development.

From this dissertation, entrepreneurs can learn about the importance of the window-in function of interactions. Entrepreneurs play a key role in valorising academic knowledge in commercialized products. Their core business is to create a commercialized product, establish it in the market and make profits based on that product. While window-out interactions might be naturally high on entrepreneurs' agendas because their core business is characterised by 'selling' the technology to other stakeholders, they could also address window-in interactions. Societal needs and values and potential pitfalls of the technology can be detected at an early stage by engaging with stakeholders, for instance, through co-creation. This might lead to more socially robust innovations and can increase legitimacy, which helps attract resources and to approach or create a market formation. Furthermore, it might limit financial losses because (potential) flaws in immature products can be detected.

7.5 Conclusion

The successful development and implementation of technological innovations requires the mobilisation of different stakeholders who all have their own interests and stakes in the innovation. This dissertation illustrates how stakeholder interactions can facilitate technological change. It distinguishes between processes that serve window-out and window-in functions. The former address interactions aiming for a positive perception of the innovation among other stakeholders and supports the creation of legitimacy. The latter emphasise the inclusion of stakeholders' needs and values in the innovation process, which can contribute to socially robust innovations. The empirical studies show the importance of both types of interactions throughout the whole innovation process, from the (early) developmental phase to the implementation phase. Furthermore, the studies illustrate that no single stakeholder is responsible for or able to steer and control the innovation process. Instead, multiple stakeholders along the value chain share mutual agency and affect the innovation through their perceptions and interactions. As such, this dissertation regards the role of communication as the process by which stakeholders manage, create and sustain the meaning of the innovation through their interactions. It contributes to a better understanding of how stakeholder interactions influence the development and implementation of technological innovations, and more specifically, how these interactions can support the creation of legitimacy and contribute to socially robust innovations.

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Samenvatting

(summary in Dutch)

Verbinden en beïnvloeden: hoe interacties tussen stakeholders technologische veranderingen mogelijk maken

De wereld van vandaag heeft te maken met grote maatschappelijke uitdagingen zoals klimaatverandering, uitputting van natuurlijke bronnen, vergrijzing en recentelijk het uitbreken van een pandemie. Voor oplossingen wordt vaak de hoop gevestigd op gedragsverandering en technologische innovaties. Een succesvolle implementatie en ontwikkeling van technologische oplossingen is echter niet vanzelfsprekend. Naast de technische uitdagingen zijn er sociale aspecten die veel impact kunnen hebben. Een technologische innovatie is daarmee tegelijkertijd een sociale innovatie. Bij de ontwikkeling en implementatie van technologische innovaties zijn namelijk verschillende stakeholders betrokken die elk hun eigen belangen en percepties hebben. Interacties tussen hen zijn van wezenlijk belang. Het doel van dit proefschrift is te onderzoeken hoe deze stakeholder-interacties technologische verandering kunnen beïnvloeden. Om hier antwoord op te kunnen geven, wordt gebruik gemaakt van concepten uit drie relevante onderzoeksgebieden: innovatiestudies (STS), communicatiewetenschap en wetenschapscommunicatie. Op basis van deze concepten zijn twee doelstellingen geformuleerd.

De eerste doelstelling is een overzicht te geven van mogelijke stakeholder-interacties die de ontwikkeling en implementatie van technologische innovaties beïnvloeden. In de innovatieliteratuur worden technologische innovaties vaak als een sociaal-technologisch systeem benaderd. Vanuit dit systeemdenken is er niet alleen aandacht voor de technische aspecten van innovaties, maar ook voor de sociale en maatschappelijke aspecten zoals culturele betekenis, de praktijk van de gebruiker, regelgeving, en productieprocessen. Hierbij wordt de nadruk gelegd op de non-lineaire ontwikkeling van technologie. Dit betekent dat technologische innovaties niet een rechtlijnig pad volgen van onderzoek naar implementatie, maar dat aanpassing op al deze aspecten nodig is. Verschillende stakeholders zoals onderzoekers, beleidsmakers, actoren in het bedrijfsleven, maatschappelijke organisaties, eindgebruikers en burgers, maken deel uit van dit systeem met elk een eigen invloed (Köhler et al., 2019). Hoewel op basis van dit systeemdenken een goed beeld wordt verkregen in de complexiteit van innovatieprocessen, hebben verschillende onderzoekers benadrukt dat er meer aandacht nodig is voor de wijze waarop betrokken partijen in hun interacties het innovatieproces vormgeven (Borrás & Edler, 2014; Geels & Schot, 2007; Köhler et al., 2019; Markard & Truffer, 2008b; Smink, 2015).

De tweede doelstelling betreft een nadere verdieping van de eerste doelstelling. Zij richt zich op de interacties die nodig zijn voor het verkrijgen van legitimiteit en het creëren van 'maatschappelijk robuuste' innovaties. Technologische oplossingen voor maatschappelijke uitdagingen zijn vaak vernieuwend. Zij zijn gebaseerd op complexe innovatieprocessen die verandering van rollen en gedragingen van stakeholders vergen. Ook kunnen zij een grote maatschappelijke impact hebben. Daarom worden deze oplossingen ook wel 'radicale innovaties' genoemd. Het lastige bij de ontwikkeling en implementatie van dit type innovaties is dat deze in eerste instantie onbekend zijn bij veel (potentiële) stakeholders en niet altijd passen binnen de bestaande normering en regelgeving. Voorstanders moeten daarom veel moeite steken in het verkrijgen van legitimatie van radicale innovaties. Een innovatie is pas legitiem als deze als wenselijk en gepast wordt gezien door de stakeholders die deze kunnen beïnvloeden of erdoor worden beïnvloed. Stakeholders kunnen legitimiteit creëren of vergroten op verschillende manieren, bijvoorbeeld door positieve bekendheid ten aanzien van de innovatie te genereren (framing); relevante regelgeving te beïnvloeden (lobbyen); het innovatieproces op een democratische manier te laten verlopen (participatie); of de innovatie beter te laten aansluiten op de wensen en behoeften binnen de maatschappij. Dit laatste punt wordt ook wel het creëren van 'maatschappelijk robuuste' innovaties genoemd. Er is echter nog veel onbekend over hoe stakeholders deze processen in de praktijk kunnen brengen en hoe de interacties daadwerkelijk bijdragen aan legitimiteit en maatschappelijk robuuste innovaties (e.g., Binz et al., 2016; Leeuwis & Aarts, 2011; Schuijff & Dijkstra, 2020).

Om beide doelstellingen te realiseren worden in dit proefschrift vijf empirische studies beschreven. Hierin worden diverse technologieën bestudeerd vanuit meerdere stakeholder-perspectieven en op basis van verschillende onderzoeksmethoden. Deze brede benadering biedt ons de mogelijkheid om te reflecteren op de rol van communicatie in innovatieprocessen.

Hoofdstuk 2 beschrijft de relevante interacties tijdens de ontwikkeling en implementatie van radicale innovaties, geïnitieerd door technologische startups. Daartoe zijn semigestructureerde interviews gehouden met 24 ondernemers die binnen verschillende sectoren actief zijn (met name de gezondheidszorg, duurzaamheid, veiligheid, ITC en 'slimme materialen'). Om de interviews op een gestructureerde manier te analyseren is gebruik gemaakt van de functionele benadering van het technologische-innovatie-systeemperspectief (TIS) dat verschillende functies onderscheidt die van belang zijn in een innovatieproces. De resultaten laten zien dat de ondernemers een breed scala aan interactieprocessen van belang achten, namelijk: framing en uitleggen van de technologie, initiëren van media-aandacht, netwerken, lobbyen, samenwerken, kennisontwikkeling, advies inwinnen en maatschappelijke adaptatie. Van de vijf onderscheiden functies worden mobilisatie van (financiële) middelen en legitimiteit door de ondernemers het meest genoemd, gevolgd door ondernemerschap, marktvorming en in mindere mate kennisontwikkeling. Interacties blijken in het hele innovatietraject essentieel; zowel om over de technologie te communiceren als om op basis van de percepties van andere stakeholders de technologie te verbeteren.

Hoofdstuk 3 gaat over legitimatie van technologische innovaties in het publieke domein. De legitimatie van genetisch gemodificeerd voedsel staat centraal en is onderzocht door middel van een media-analyse van 287 Nederlandse krantenartikelen die tussen 1996 en 2016 over deze technologie zijn verschenen. De artikelen zijn geanalyseerd op basis van het 'technologie-legitimatie' raamwerk, ontwikkeld door Binz et al. (2016), dat uitgaat van vier pijlers van legitimatie, te weten: cognitief, normatief, regulatief en pragmatisch. De media-analyse laat zien dat in het twintig jaar durende publieke debat over genetisch gemodificeerd voedsel de normatieve pijler domineerde. De cognitieve pijler, het vergroten van kennis over de technologie en haar effecten, bleek eveneens van belang. Minder vaak werd gerefereerd aan de regelgeving (regulatieve pijler) en het praktisch nut van de technologie (pragmatische pijler), terwijl deze laatstgenoemde pijler juist overwegend positief werd geadresseerd en de andere drie overwegend negatief. Dit geldt in het bijzonder voor de normatieve pijler, die gedomineerd werd door emotionele retoriek. In deze studie zijn voor het eerst de legitimatiepijlers als methode gebruikt om de legitimiteit van een technologie in het publieke domein te analyseren. De toepasbaarheid van die pijlers toont de relevantie van de methode om de legitimiteit van technologische innovaties in het publieke debat te analyseren.

Hoofdstuk 4 beschrijft twee onderzoeken (focusgroepen (N=24) en surveyonderzoek (N=1245)) naar de percepties van woningbezitters en huurders ten aanzien van de transitie naar aardgasvrije verwarming. Uiteindelijk kunnen beide groepen worden gezien als toekomstige eindgebruikers van (duurzame) alternatieven voor aardgas. Hun rol in de transitie kan echter wezenlijk verschillen. Door het inzicht in de percepties van beide groepen te verbeteren, kunnen strategieën voor succesvollere communicatie worden vormgegeven. De resultaten van beide studies laten zien dat woningbezitters en huurders, ondanks hun verschillende rollen in de transitie, dezelfde thema's belangrijk vinden. Zij hebben veel interesse in de transitie, willen ruimte om actief te participeren en hechten aan dezelfde kenmerken waaraan de alternatieven voor aardgas moeten voldoen. Verder blijken vertrouwen in verantwoordelijke actoren (voornamelijk overheden) en zorgen om het klimaat belangrijke voorspellers te zijn van de attitude ten aanzien van de transitie. Deze resultaten geven beleidsmakers handvatten om acceptatie en participatie van beide groepen te bevorderen in de transitie naar aardgasvrije woonwijken.

Hoofdstuk 5 legt het accent op maatschappelijk robuuste innovaties door burgers te betrekken bij de ontwikkeling. Het beschrijft een studie van acht uitgebreide focusgroepen (N=50) waarin burgers werd gevraagd suggesties te geven voor toepassingen van nanotechnologie in de gezondheidszorg. Het onderzoek richt zich op de vraag welke aspecten van technologische innovaties burgers een bijdrage kunnen leveren en vanuit welke waardenoriëntatie zij dat doen. De resultaten laten zien dat burgers zes verschillende aspecten van de technologie bespraken. Zij legden de meeste nadruk op implementatie en gebruik, in mindere mate op het systeem en de ontwikkeling en de minste op het ontwerp en de communicatie over de technologie. De meeste suggesties betreffen de voorwaarden waaronder burgers gebruik willen maken van de technologie. Waarbij zij zichzelf verplaatsten in de rol van eindgebruiker. Daarnaast legden burgers een link tussen het zorgsysteem, de technologie en hun eigen behoeften. Deze suggesties zijn gebaseerd op zorgen over mogelijke consequenties van de technologie en voornamelijk gerelateerd aan de waarden welzijn, autonomie, en bescherming van hun privacy.

Hoofdstuk 6 analyseert hoe stakeholders door co-creatie samen meer waarde en betekenis aan innovaties kunnen geven. De studie is gebaseerd op een vergelijking van drie co-creatieworkshops met verschillende typen stakeholders, bestaande uit onderzoekers, ondernemers, beleidsmakers, maatschappelijke organisaties en burgers. De workshops zijn geanalyseerd op basis van de vier kerndimensies van verantwoord innoveren: reflexiviteit, inclusie, anticipatie en adaptatie (Stilgoe et al., 2013). Deze dragen bij aan legitimatie en maatschappelijk robuuste innovaties. De resultaten laten zien hoe lastig het is om in een workshop aan alle vier dimensies in gelijke mate te voldoen. De opzet en inrichting van de workshops, de aan- of afwezigheid van bepaalde stakeholders en de specificiteit van de

vraagstelling beïnvloeden de bijdrage van de deelnemers. Dit suggereert dat er in het co-creatieproces een afweging moet worden gemaakt tussen een focus op legitimatie en op de toegevoegde waarde van de innovatie. Ligt de nadruk op de toegevoegde waarde, dan vereist het co-creatieproces een vroegtijdige ontwikkelfase van de innovatie die specifiek gekoppeld is aan het perspectief van één of meer stakeholders. Dit kan ten koste gaan van de inclusiviteit van het co-creatieproces en van de mogelijkheid om diepgaand te anticiperen op de maatschappelijke consequenties van een innovatie.

Uit bovenstaande studies wordt geconcludeerd dat interacties tussen relevante stakeholders twee functies dient. De eerste functie, *window-out*, is gericht op communicatie over de technologie naar andere stakeholders en omvat interacties als framing, informatieverstrekking, lobbyen en het creëren van media-aandacht. Deze functie draagt bij aan een positief beeld van de innovatie, wat de legitimiteit vergroot en helpt bij het verkrijgen van (financiële) middelen en marktformatie. De tweede functie, *window-in*, richt zich op het betrekken van verschillende stakeholderperspectieven in het innovatieproces, met als doel de maatschappelijke robuustheid van innovaties te vergroten. Dat kan een positief effect hebben op legitimiteit, ondernemerschap, kennisontwikkeling en marktontwikkeling. Deze functie omvat interacties als publieke- en stakeholderparticipatie, maatschappelijke adaptatie en samenwerking met anderen. De window-in-interacties onderstrepen een non-lineaire ontwikkeling van innovaties, waarbij de toepassingen van de technologie tijdens het proces worden aangepast.

Dit proefschrift demonstreert het belang van communicatie in het innovatieproces. De verschillende studies laten zien dat zowel de window-out- als window-in-interacties tijdens het gehele traject van belang zijn. Van de vroege fases in de ontwikkeling tot de implementatie. Ook illustreren de verschillende studies dat niet één bepaalde stakeholder verantwoordelijk of bij machte is om het gehele innovatietraject te sturen. Dit proefschrift toont aan dat communicatie een belangrijke rol speelt bij het creëren van legitimiteit en het vergroten van de maatschappelijke robuustheid van innovaties.

Biography

About the author

Sikke Ruurd Jansma was born on 4 January 1988 in Leeuwarden. He grew up in Garyp, a small village in the province of Friesland in the Netherlands. In 2006, he moved to Enschede for his bachelor's degree in communication science at the University of Twente. The green campus, the pleasant atmosphere and the intellectual environment, including fellow students and staff, made him feel at home. Therefore it is not surprising that he came back to this place as a PhD-student. Before doing so, he studied in Seattle for an exchange programme at the University of Washington and in Amsterdam for his master's degree in political science (cum laude) at the Vrije Universiteit Amsterdam.

Starting his career as a PR-consultant, Sikke returned at the end of 2013 to the University of Twente as a teacher at the department of Communication Science. He taught academic and professional skills and later gave courses related to communication of science and technology and the course public affairs. During his teaching activities, he became increasingly interested in doing research on the social dynamics around technological innovations. He got the opportunity to focus on a subject in which the insights from communication science are combined with those of political science, within the technology-oriented context of the University of Twente. Under supervision of prof. dr. Menno de Jong, dr. Jordy Gosselt and dr. Anne Dijkstra, he studied the role of communication in the development and implementation of technological innovations. From 2018 to 2020 he worked as a fulltime researcher in the Horizon2020-project GoNano about responsible research and innovation of nanotechnology in health through co-creation and the living lab project Aardgasvrij about stakeholder and citizen communication in the transition towards sustainable heat for the province of Overijssel.

Currently, Sikke works as a teacher and researcher at the department of Communication Science at the University of Twente. His research interests are in the field of legitimation of technological innovations, democratization of science and technology, citizen and stakeholder engagement in the development and implementation of technological innovations. Contexts of interests are nanotechnology, renewable energy technologies, genetically modified organisms, and vaccinations.

Scientific publications

Nab, M., Jansma, S. R., & Gosselt, J. F. (2020). Tell me what is on the line and make it personal: Energizing Dutch homeowners through message framing. Energy Research & Social Science, 70, 101760-101770. doi:10.1016/j.erss.2020.101760

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Jansma, S. R., Gosselt, J. F., & de Jong, M. D. T. (2019). Citizen engagement in the transition towards sustainable heat. Paper presented at the 2nd international conference on Energy Research and Social Science, Phoenix, AZ.

Jansma, S. R., Dijkstra, A. M., & de Jong, M. D. T. (2019). Engaging the general public in the development of nanotechnology. Paper presented at the annual meeting of the Netherlands-Flanders Communication Association, Nijmegen, The Netherlands.

Jansma, S. R., Gosselt, J. F., Kuipers, K., & de Jong, M. D. T. (2018). Frankenstein food? Legitimation of GM food in the Netherlands. Paper presented at the bi-annual conference of the Public Communication of Science and Technology (PCST), Dunedin, New Zealand.

De Jong, M. D. T., Neulen, S., & Jansma, S. R. (2017). Co-creation between citizens and the government. Paper presented at the annual meeting of the Netherlands-Flanders Communication Association, Tilburg, The Netherlands.

Jansma, S. R., Gosselt, J. F., & de Jong, M. D. T. (2016). The role of communication in the development and implementation of technological innovations. Paper presented at the annual meeting of the Netherlands-Flanders Communication Association, Amsterdam, The Netherlands.

Jansma, S. R., Barth, S., Janssen, M. G. M., & de Jong, M. D. T. (2015). Push or match? Een vergelijking van informatiebehoefte van burgers en aangeboden informatie van partijen en media tijdens verkiezingen [Push or match? A comparison of citizens' information needs and the published information by political parties and media during election time]. Paper presented at the annual meeting of the Netherlands-Flanders Communication Association, Antwerp, Belgium.

Research projects

Aug. 2020 - Dec. 2020	BMS Covid-19. The legitimation of Covid-19 vaccinations: quantitative sentiment analysis of the public discourse on Covid-19 vaccinations in the Netherlands. *Funded by the faculty of Behavioural Management and Social Sciences, University of Twente.*

Jan. 2018 – Dec. 2020	GoNano-project. Governing and developing nanotechnologies through societal engagement by means of co-creation. *Funded by the European Union under the NMBP-programme of Horizon 2020, Grant Agreement n° 768622.*
Feb. 2018 – May 2019	Pilot Aardgasvrije wijken (2019). Burger en stakeholder communicatie in de transitie naar Aardgasvrij [Citizen and stakeholder communication in the transition towards sustainable heat]. *Funded by the province of Overijssel.*

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Dankwoord *(acknowledgements in Dutch)*

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