Eliciting Stakeholder Needs – An Anticipatory Approach Assessing Enhanced Landfill Mining

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Abstract

Landfill owners, governmental institutions, technology providers, academia and local communities are important stakeholders involved in Enhanced Landfill Mining (ELFM). This concept of excavating and processing historical waste streams to higher added values can be seen as a continuation of traditional landfill mining (LFM) and seems to be an innovative and promising idea for potential environmental and societal benefits. However, ELFM's profitability is still under debate, and environmental as well as societal impacts have to be further investigated. This study provides a first step towards an anticipatory approach, assessing ELFM through stakeholder integration. In the study, semi-structured interviews were conducted with various stakeholders, involved in a case study in Flanders, Belgium. Participants were selected across a quadruple helix (QH) framework, i.e. industrial, governmental, scientific, and local community actors. The research comprises 13 interviews conducted with an aim to elicit stakeholder needs for ELFM implementation using a general inductive approach. In total 18 different stakeholder needs were identified. The paper explains how the stakeholder needs refer to the different dimensions of sustainability, which groups of stakeholders they primarily affect, and what types of uncertainty could be influenced by their implementation. The stakeholder needs are structured into societal, environmental, regulatory and techno-economic needs. Results show additional economic, environmental, and societal aspects of ELFM to be integrated into ELFM research, as well as a need for the dynamic modeling of impacts.

Keywords

Enhanced Landfill Mining, stakeholder needs, anticipatory approach, sustainability, circular economy.

1. Introduction

Recent landfill mining (LFM) research has focused on the processing of waste to higher added values, and a new approach to mining landfills has emerged, leading to the concept of enhanced landfill mining (ELFM): *ELFM aims to add value to past urban waste streams as materials (Waste-to-Material, WtM) and energy (Waste-to-Energy, WtE), using innovative technology in an integrated and environmentally and socially sound way* (Jones et al., 2013). Aside from (geo)strategic considerations, potential environmental, economic, and societal benefits have made ELFM an appealing, but complex, concept for research, industry, and policymakers.

The aim of this study is to integrate stakeholders into ELFM assessment in order to identify knowledge gaps and uncertainties related to ELFM implementation through eliciting stakeholder needs. A broad stakeholder integration will enable ELFM research to better understand the structure of technology-, market, or regulatory-related uncertainties, and will enable policymakers and industrial actors to make more informed decisions. To tackle this challenge, we apply an *anticipatory approach, which* gives *specific attention to the integration of stakeholder values and the inclusion of uncertainty through the use of prospective modeling tools and multiple social perspectives* (Cucurachi et al., 2018; Wender et al., 2014).

Within this approach, analyzing stakeholder needs is a necessary first step to enable a sensible ELFM implementation. In the context of this study, *stakeholder needs are defined as expectations and requirements that various ELFM practitioners and affected groups or individuals have towards ELFM implementatio*n. To elicit these stakeholder needs we have conducted semi-structured interviews and analysis following *a general inductive approach, which aims to derive* *concepts, themes or models from textual data to create meaning* (Thomas, 2006). A well-studied ELFM case in Belgium provides the basis for a broad and accessible stakeholder environment, and the required scientific context to reasonably interpret results.

2 State of the Art

The State of the Art section reviews the current literature in ELFM research and explains how stakeholders have been integrated. It summarizes how uncertainty is treated throughout this research and gives a short overview of the regulatory framework for ELFM.

2.1 ELFM Research and Stakeholder Integration

Former research on LFM has generally been approached with a focus on solving landfill management issues, mainly landfill air space recovery, pollution concerns, and material characterization. Krook et al., (2012) give a well-established overview of research over the prior two decades. Since then, the concept of LFM has developed to ELFM and the focus has shifted to technological challenges as well as economic and environmental assessments of ELFM projects (Jones et al., 2013; Krook et al., 2018b). Nonetheless, material composition, especially the fine fraction, still plays a crucial role in the valorization of landfilled waste (Burlakovs et al., 2018; Hernández Parrodi et al., 2018), alike WtM (Garcia Lopez et al., 2018), and WtE (Bosmans et al., 2013) technology.

Assessments are usually performed either on an ex-ante basis or from small-scale pilot projects (Krook et al., 2018b). All dimensions of sustainability, i.e. economic, environmental, and societal, are assessed but a clear focus lays on economic and environmental issues. Societal factors are, to some extent, evaluated through integrated assessments but ELFM research generally lacks assessment models in this area.

Economic studies on ELFM usually take a private investor's perspective, using some form of cost and benefits aggregation like the net present value (NPV) (Danthurebandara et al., 2015a; Wagner and Raymond, 2015), and are showing mixed results depending on technology (e.g. mobile vs local separation) or methodological choices (e.g. resource prices) (Van Passel et al., 2013; Zhou et al., 2015). However, overall studies show a tendency for ELFM not being profitable. Some economic assessments integrate a societal perspective by contrasting private and public scenarios (Winterstetter et al., 2018, 2015) or the monetization of environmental externalities (Van Passel et al., 2013). The dominant method to evaluate the environmental dimension of ELFM is life cycle assessment (LCA) (Danthurebandara et al., 2015b; Frändegård et al., 2013a; Gusca et al., 2015; Jain et al., 2014; Pastre et al., 2018). Results show potential benefits but also generated burdens.

The integration of stakeholders has only been touched upon superficially by ELFM research; it is usually not carried out in a comprehensive manner and includes only selected experts. Johansson et al. (2012) studied five different landfills in Sweden to identify key challenges and critical factors for a shift towards (E)LFM implementation, and conclude that exogenous changes, e.g. legislation, might be necessary. They integrate the project owners through interviews and other industrial stakeholders through historical documents such as old invoices and shipping documents to provide a historical overview of the landfill structure (Johansson et al., 2012). Similarly, a later study interviews experts from a recycling company and integrates institutional stakeholders through legislative texts (Johansson et al., 2017). Hölzle (2019) includes a broader range of stakeholders for a material flow analysis (MFA). Furthermore, he investigates influencing factors and uses various documents, including regulations and reports from engineering consultants and environmental agencies, amongst others, as well as stakeholder interviews to conduct a PEST (political, economic, socio-cultural and technological) analysis. He identifies a large variety of factors in the categories of landfill, technology, economy, organization and institutions/laws (Hölzle, 2019). Hermann et al. (2016) develop a decision-making procedure also using interviews and focus groups with institutional and industrial experts along the value chain of ELFM. They combine economic and environmental assessments and integrate the societal dimension into a holistic model. They derive four socio-economic criteria, i.e. interests of operators, neighbors, and authorities, as well as the space required for conversion of the landfill. This preliminary assessment, using a ranking system, is carried out by means of a questionnaire to derive utilities that again serve as input data for the main assessment, where effects become entangled (Hermann et al., 2016b, 2015). Two other studies use contingent valuation methods (CVM) to monetize societal benefits (Damigos et al., 2015; Marella and Raga, 2014). Marella and Raga (2014), for example, use willingness-to-pay (WTP) to assess the welfare increase through the creation of a public park after ELFM operations and calculate a surplus of about 200 euros per capita. These studies include community actors through questionnaires but are based on hypothetical scenarios and the derived monetary values comprise multiple societal effects (Marella and Raga, 2014). Pastre et al. (2018) also consider communities in their assessment tool for ELFM in the form of a ranking system for societal factors, but stakeholders have not been involved in the development of the tool.

2.2 Uncertainty in ELFM Research

Most case studies on the performance of ELFM have a prospective character, assessing potential future outcomes. Additionally, different methodological choices and case-specific circumstances affect their comparability (Krook et al., 2018b). These include site-specific issues like waste composition, technology choices or contextual factors, and often limit the generalization of results. In consequence, the general results of ELFM studies are subject to considerable uncertainties.

In some studies, different types of uncertainties are mentioned. These are mostly market (van der Zee et al., 2004), technology (Frändegård et al., 2013b), or society (Pastre et al., 2018) related. Several studies, however, do address uncertainty through sensitivity analyses. Economic costs and benefits or the variation of NPVs due to market uncertainties (e.g. material, electricity or land prices) are analyzed (Danthurebandara et al., 2015a; Kieckhäfer et al., 2017; Van Passel et al., 2013; Winterstetter et al., 2015), as well as variations of environmental factors affecting greenhouse gas (GHG) emissions, for example (Frändegård et al., 2015, 2013b; Laner et al., 2016). Bobe and Van De Vijver (2019) already take uncertainty into account during the exploration phase and therefore make it clear that data along all stages of ELFM assessment should be treated probabilistically rather than deterministically. However, to understand the relationship between different factors, as well as the distributions, is crucial since a bad choice in probability distributions could lead to overall more uncertainty. Moreover, types of uncertainty are not differentiated, nor their interaction with each other.

2.3 The Regulatory Situation of ELFM

In Europe, the so-called Landfill Directive sets the standard for managing current landfills (Council Directive, 1999). Amongst other areas, it regulates operational, financial, and safety issues. During operations, a landfill runs through several stages: the landfilling period, the after-care period, and the release from after-care (Council Directive, 1999). In case of ELFM implementation, conceptually, a mining and an after-use period would be added. Additionally, the Landfill Directive sets regulations for safety and sanitary landfill design, including liners and LFG collection systems, for example (Council Directive, 1999). Regulations for the treatment of hazardous waste are further defined in the Waste Directive (Council Directive, 2008). A large number of landfills predating these directives, however, cannot be considered sanitary and might pose potential risks (Jones et al., 2013; Krook et al., 2018a). They are commonly referred to as "Dump Sites".

In May 2017 the European Council has rejected the ELFM Amendment to the Landfill Directive (Jones et al., 2018) making the regulatory situation for ELFM somewhat vague. Yet the answer of the European Commission (EC) to a parliamentary question states that "Landfill mining is […] not prohibited […]" (Jones et al., 2018). A legal report for the Austrian LAMIS project supports that statement and concludes that the current legal framework does not hinder ELFM operations, even at a larger scale (Eisenberger, 2015). In Flanders, OVAM, the environmental agency is responsible for soil remediation, waste, and sustainable materials management, and also in charge of Flemish landfill regulations. A vision on ELFM was approved by their board of directors in 2011 (Behets et al., 2013). The Flemish Coalition Agreement 2014-2019 mentions the recovery of resources from landfills (Wille, 2016) and OVAM is developing a database on the current landfill situation, including contamination risks and resource potentials (Winterstetter et al., 2018).

3 Method and Materials

Eliciting stakeholder needs was an iterative process, starting with a literature review. From the gained knowledge, an interview guide was developed and potential interviewees identified. Two rounds of interviews were conducted. The interviews were recorded and transcribed, and analysis was carried out eliciting stakeholder needs. A schematic representation of the various steps involved in this method can be found in Figure 1. This section further describes the case study as well as the stakeholder selection.

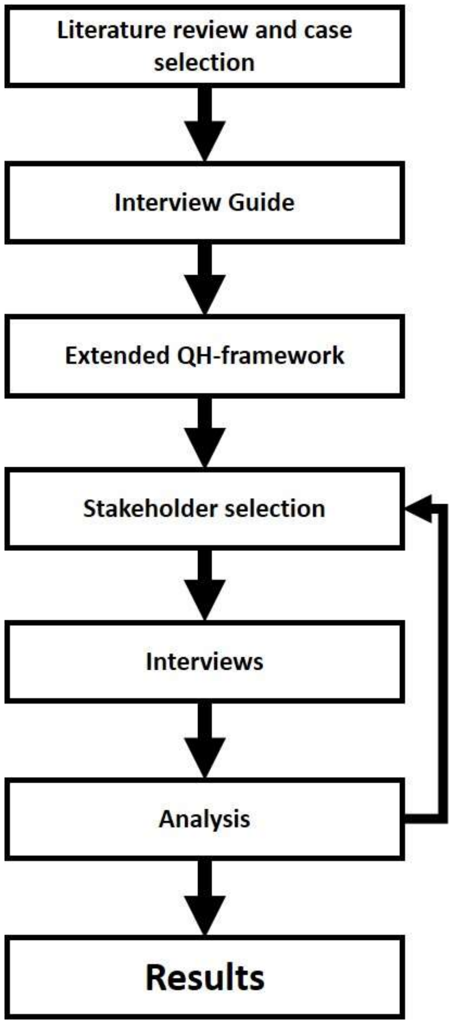
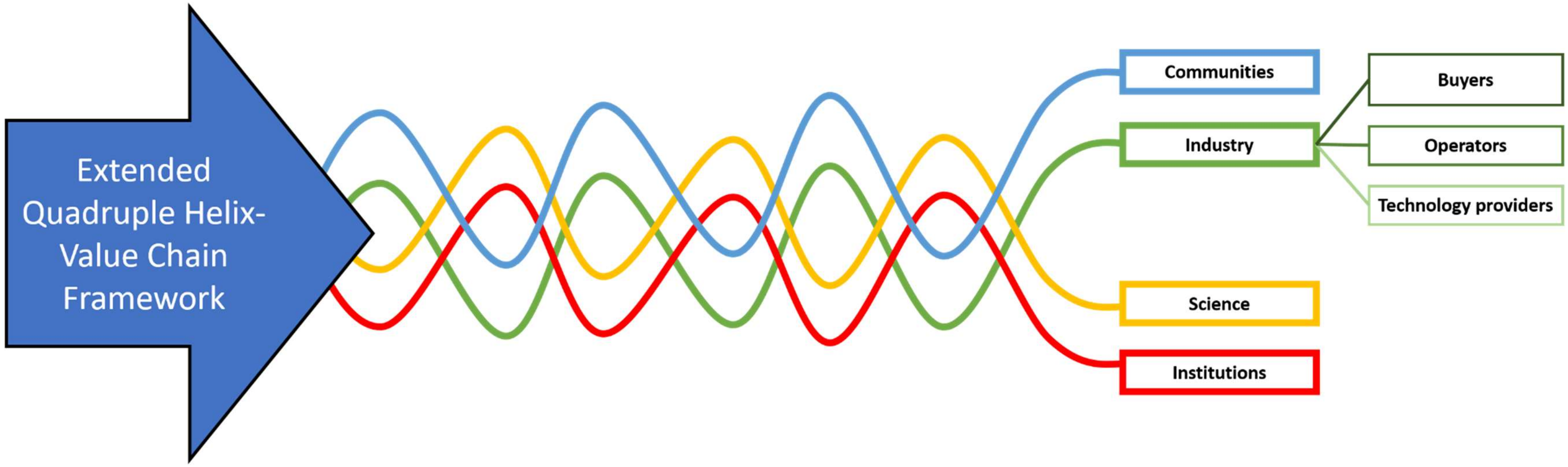


Figure 1: A schematic representation of the methodological approach.

3.1 Stakeholder Identification

A combined quadruple helix (QH)-value chain framework provided the basis for the initial stakeholder identification. *The QH approach distinguishes between various actors at different points of innovation processes to capture multiple, reciprocal relationships between them* (Arnkil et al., 2010; Kolehmainen et al., 2016). In the context of this study, it included actors from (i) local communities, (ii) institutions, (iii) industry, and (iv) research. Stakeholders were further subcategorized by adding new levels of differentiation along the value chain of ELFM. Industrial actors were subclassified into operators, technology providers, and buyers. The extended QH-value chain-framework is illustrated in Figure 2. Preliminary results contributed to an additional stakeholder selection: During the interviews, new potential participants were identified using respond-driven sampling, i.e. snowballing (Goodman, 1961; Heckathorn, 1997). A second round of interviews was conducted and the analysis finalized.



1 *Figure 2: The Quadruple Helix-Value Chain Framework.*

3.2 Analysis

For analysis, a general inductive approach was used, including three major steps, in which the raw data is condensed into a brief summary format, clear links and relations are established between the findings and the research objective, i.e. stakeholder needs, and a theoretical framework about the underlying structure is developed (Thomas, 2006). Interviews were taken in person or by phone. To elicit the stakeholder needs, interviewees were not just simply asked directly. Open questions about landfills, ELFM in general, and the case study were used and needs derived at a later stage. A list of these questions can be found in the Appendix. To process the large amount of data (c.f. Section 4) QSR International's NVivo 11 software was used. This enabled us to easily structure and extract relevant statements through coding, which established links and relations between specific stakeholders or stakeholder groups, and statements. Coding categories were adapted and refined throughout the analysis (Stemler, 2003; Thomas, 2006). Overlapping coding was allowed, opening up the possibility of one statement being assigned to several coding categories, hinting to links between them. In practice, statements and ideas mentioned by participants were assigned to specific coding (sub)categories and linked to their stakeholder group. An overview of the coding categories can be seen in Figure 3. Statements, expressing stakeholder needs, were then summarized in tables and grouped thematically to derive more general themes of interest. Through the coding, it was possible to derive which stakeholder needs refer to different dimensions of sustainability and to identify the range of effects in case of implementation of a need, i.e. perceived effects on stakeholders and regions. Linking the stakeholder needs to different sustainability dimensions will reveal inter-dimensional relations and help to identify potential trade-offs. How the implementation of the stakeholder needs will affect economic, environmental and societal impacts is explained in more detail throughout the text (cf. Section 4).

To identify critical factors for uncertainties, consequently reduce the level of uncertainty in ELFM, and facilitate its further development, it is important to differentiate and assess how various processes are affected as well as how different types of uncertainty interplay with the stakeholder needs. Five different types of uncertainty are differentiated: ***Technological uncertainty*** *(TU) describes the influence of unknown factors on future technological innovation, while* ***market uncertainty*** *(MU) describes unknown market-related effects.* ***Regulatory uncertainty*** *(RU) is derived from doubts about future regulatory frameworks, whereas* ***environmental uncertainty*** *(EU) expresses unknown variations of environmental burdens and benefits. Finally,* ***social uncertainty*** *(SU) is defined as the influence of unknown factors on the social benefits and burdens of a project*. These definitions are derived from various references and adapted to fit the purpose of this study (c.f. Hoffnmann et al., 2009; Refsgaard et al., 2007; Seidl and Lexer, 2013).

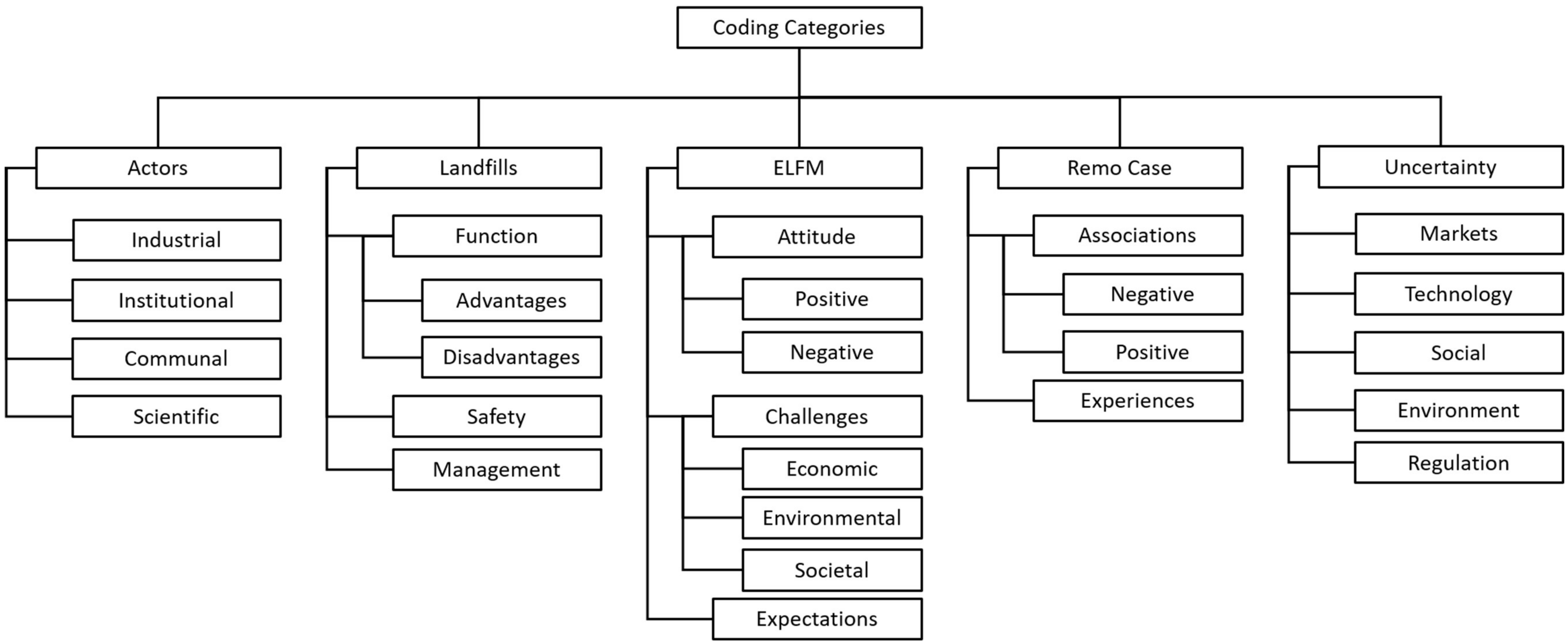


Figure 3: The emerged coding categories.

3.3 Case study and Sampling

It was considered important to choose interviewees with active engagement in an applied ELFM case. This would enable participants having actual experiences and consider real implications of their statements, rather than hypothetical ones to increase the relevance of results (Bryson, 2004; Prell et al., 2008). The case should provide a broad stakeholder environment and should be subject to prior scientific research.

3.3.1 The Remo Case

The Remo landfill, located in the Flanders region of Belgium, generally meets these conditions (Bosmans et al., 2013; Danthurebandara et al., 2013; Quaghebeur et al., 2013; Van Passel et al., 2013). The landfill lies within a densely populated area and is surrounded by several smaller communities (Geysen, 2017; Group Machiels, 2018; Quaghebeur et al., 2013). In 2008 the "Closing the Circle" (CtC) project was introduced by the operators, aiming to establish ELFM operations at an industrial scale at Remo (Group Machiels, 2018). Permitting processes have started and the operators are in contact with the relevant institutions. These plans grabbed the attention of local citizens. Members of the surrounding communities are self-organized in a group called "De Locals". This group seeks to gather information about the planned ELFM activities at Remo and distribute it amongst residents. They have been following the ELFM project at Remo critically for about 7 years (Ballard et al., 2018).

3.3.2 Stakeholder Selection

The Remo case involves stakeholders from all four QH-classes. An approximate evenly distributed share of participants over the QH-classes and a high level of case-involvement were prioritized criteria for the first selection of interviewees. The initial group of participants was selected by the researchers and aimed at the core stakeholders. It comprised eight interviews, including two members of "De Locals", two actors from the regional waste agency, one European policymaker, one researcher, and two managers from the operating company. Five additional interviews were held in the second round. These included one community member, a leading member of the local government, and two actors from technology providers being part of the CtC project.

Including buyers of ELFM products was a difficult task for two main reasons: First, as operations have not started, no actual buyers exist; second, the wide range of outputs ELFM might be offering is still subject to investigations. It is unclear, which technological and economic way ELFM will take, and thus, difficult to identify potential customers for ELFM products (cf. Van Passel et al. 2013; Bosmans et al. 2013; Krook et al. 2018). To compensate this gap, one additional interview was held with a manager from an energy and recycling technology incubator, working closely with potential purchasers of ELFM products and operating within a similar region. An overview of all participants can be found in Table 1.

Table 1: Interviewees sorted by stakeholder class.

QH-Value Chain-Class	**Stakeholder**	**No.**	
Community members			**3**
	De Locals	3	
Institutional actors			**4**
	Local Government	1	
	Waste Agency	2	
	European Government	1	
Scientific actors			**1**
	Researcher	1	
Industrial actors			**5**
	Operators	2	
	Technology providers	2	
	Technology incubator	1	
Total			**13**

4 Results

The interviews took on average 54 minutes. The raw textual data comprised over 70.000 words. In total 18 different stakeholder needs were identified. The analysis led to the categorization of stakeholder needs into four major clusters: (i) societal needs, (ii) needs for environmental benefits, (iii) regulatory needs, and (iv) techno-economic needs. This section is structured accordingly. The last sub-section treats the five types of uncertainty (c.f. Section 3.2). An overview of the stakeholder needs can be found in Table 2.

Table 2: Overview of the different stakeholder needs arranged by categories.

No.	Category	Stakeholder Need	Stakeholders	Affected sustainability dimension	Range	Affected types of uncertainty
1	Societal needs	Protection against disamenities	Community members	Econ., Env., Soc.	Local to regional	SU, EU, RU
2		Employment		Econ., Soc.	Local to regional	SU, MU
3		Communal benefits	Community members and local government	Econ., Soc.	Local to regional	SU
4		Stakeholder involvement	All stakeholders	Econ., soc.	Local to global	SU, MU
5		Safety		Econ., Env., Soc.	Regional to supranational	SU, RU
6	Environmental Needs	Avoided Impacts	All stakeholders	Env., Soc.	Local to global	EU, SU
7		Mitigation of systematic risks	Regional waste agency	Econ., Env., Soc.	Regional	EU, RU
8		Landfill conversion		Env., Soc.,	Local to regional	EU, SU
9	Regulatory needs	Regulatory changes	Industrial, institutional and scientific actors	Econ., Soc.	Regional to supranational	SU, RU, EU

10		Interim-use	Regional waste agency	Econ., Env., Soc.	Local to regional	SU, RU, EU, MU
11		Public investment support	Industrial actors	Econ., Soc.	Local to supranational	SU, RU
12		Recognition of regional differences		Econ., Env., Soc.	Local to regional	SU, RU, EU
13		Economic growth	Industrial actors and local government	Econ., Env., Soc.	Regional to supranational	MU
14		Technological development	Institutional and industrial actors	Econ., Env., Soc.	Global	TU, MU
15	Techno-economic needs	Material recuperation	European government and operators	Econ., Env., Soc.	Local to regional	EU, MU
16		Land reclamation	Institutional actors and operators	Econ., Soc.	Local	MU, SU
17		Pilot projects	Operators	Econ., Soc.	Local to supranational	MU. TU
18		Flexible valorization routes		Econ., Env., Soc.	Local to regional	MU, TU, EU

4.1 Societal Needs

Five stakeholder needs mainly affect public acceptance, and are thus considered societal needs. In this context, *public acceptance is defined as approval of an ELFM project by public stakeholders, i.e. institutional and community actors*. Interestingly, all needs are considered to influence ELFM implementation on a local or local to regional level and are expressed by either local community members or multiple stakeholder classes including local community members. The needs perceived solely by local community members are protection against disamenities, (1) and creation of employment (2).

The first stakeholder need (1) is expressed through the expectation of citizens to experience discomfort through noise, odor, dust or increased traffic coming from ELFM operations. While societal effects might be quite obvious by increasing public acceptance and the well-being of citizens, economic and environmental effects are also implied. Changing transport routes or means (e.g. from road to rail), for example, can influence environmental emissions of an ELFM project as well as private costs. Local community members and operators are mainly affected, defining the range of effects to be local to regional.

The need for creation of employment (2) could also be categorized in relation to techno-economic needs. Nevertheless, being expressed by local community members and aiming towards societal benefits of local and regional growing labor markets, it was considered to mainly affect public acceptance. The essence of this need is its effects on the societal and economic costs and benefits. While an increase in employment increases public acceptance and could generate economic growth through secondary income effects, it also raises private costs at a project level.

Effects of creating employment mostly affect local community members and reach out locally to regionally, albeit ELFM implementation at an industrial scope could affect economic growth on a federal or even supranational level.

The next three stakeholder needs were expressed by multiple actors (c.f. Table 2) and include communal benefits (3), stakeholder involvement (4), and safety (5). Need 3 exceeds relative benefits through lessened disamenities or increased employment and can include monetary and non-monetary benefits like the creation of public recreational land, communal engagement, financial compensations or increased property prices depending on the after-use of the excavated landfill. Creating such benefits can lead to public and private costs and benefits. As the name of this need already suggests, impacts are considered to reach local to regional levels, affecting mostly local communities and governments.

Stakeholder involvement (4) is being perceived as one of the biggest societal challenges by all participants. Operators are not only motivated to distribute knowledge and information in order to increase public acceptance but also to promote ELFM to investors. This need affects societal and economic factors through the generation of private and public costs for information material, lobbying or the use of public infrastructure. It goes beyond the project level, including actors along the value chain and international organizations, impacting at local to global levels.

The need for safety (5) is perceived with various notions depending on the stakeholder class. Operators expressed concerns for the safety of workers, while community members referred the concept to socio-environmental risks like groundwater contamination or the reintroduction of toxic substances into material circles. The scientific actor perceived a safety risk for a lack of control mechanisms of already in-place regulations. A lack of safety mechanisms can lead to environmental damages as well as public and private costs. While this need could be further differentiated into environmental safety and workers' safety, for example, it essentially originates in ELFM operations and is expressed by all stakeholder classes. Therefore, all safety issues are summarized under this need.

4.2 Environmental Needs

All stakeholders perceived a general need for ELFM being environmentally beneficial. Nonetheless, environmental needs were mainly expressed by institutional actors (c.f. Table 2). These needs included the need for avoided impacts (6), the reduction of long-term systematic environmental risks (7), and landfill conversion (8).

General environmental benefits of ELFM are expected to mainly be achieved through the mitigation of primary resource consumption and long-term landfill impacts. Need 6 has a local to global range and primarily refers to environmental and societal issues.

Reducing long-term systematic risks (7) aims to prevent future, unforeseen environmental impacts due to climatic changes at a systematic level. Through changes in precipitation, for example, risks concerning groundwater contamination also change. If certain regions are exposed to higher flood risks in the future, mining landfills within these regions would reduce the systematic risk for groundwater contamination in that region (c.f. Wille, 2018). The mitigation of risks alike could imply public and private costs for preventive measures, making this a three-dimensional need.

The need for landfill conversion (8) was expressed by the regional waste agency Its implementation targets the remediation of natural habitat, especially the soil, after waste removal. Hence, it is perceived as an environmental benefit and almost naturally part of ELFM. Actual impacts, however, depend on the land use after remediation. Depending on many factors like waste composition, location, ownership or the after-use, meeting this need could imply additional private or public costs and benefits. It can be expected that impacts are mainly local to regional.

4.3 Regulatory needs

Social and environmental needs are to some extent introduced to other stakeholders by the local communities. The need for regulatory changes (9), on the other hand, was mentioned by all stakeholder classes but local community members. Especially the regional waste agency as well as industrial actors perceived a need for legislation on ELFM. The regional waste agency specifically expressed a need for the interim-use of closed landfills (10) that could be mined in the future and ELFM's integration into European policy frameworks. Industrial actors stated the need for public investment support (11) and the consideration of regional differences when implementing regulations (12).

Despite the impression that no current legislation is hindering ELFM implementation, industrial and scientific actors, and regional institutions would appreciate a defining legal framework. Regulatory changes imply a societal cost but can at the same time lead to changes in private cost structures and environmental impacts. This is essentially true for all regulatory needs but the need for investment support (11). While investment support in form of green certificates, for example, could lead to environmental impacts at a regional to global level as more emissions are produced, at a project level, these effects can be neglected.

The interim-use of closed landfills (10) could be part of ELFM regulation and is also a three-dimensional need. It would comprise the period after closure of a landfill and before mining operations begin. Effects of meeting this need highly depend on its implementation but would range from local to regional levels. Potential private and societal costs and benefits, as well as environmental changes, are implied when installing a solar plant at a closed landfill site, for instance.

The need for public investment support (11) was mentioned by all industrial actors unilaterally. Integrating this need into ELFM regulation could take the form of tax reliefs, subsidies or public-private partnerships. This need can potentially reach out from local communities to supranational institutions. Private economic benefits and societal costs are implied.

In the context of ELFM regulation, technology providers urged for the recognition of local and regional differences (12). This should not only take socio-economic structures into account, like population densities, but also environmental variation in soil and climatic conditions. Depending on these differences, variations in safety regulations or the interim-use could be optimized and implemented. Investment support could also vary over different regions, taking industrial symbiosis opportunities into account, for example, and relating this need to the needs 5, 10 and 11. Naturally, this need takes effect at a local and regional level.

4.4 Techno-economic needs

Economic and technological needs are combined to techno-economic needs because they are so closely related in ELFM implementation. Technological development plays a crucial role in the profitability of ELFM projects. Regarding WtM and WtE technology, most ELFM projects in the past were conducted at lab or pilot scale (c.f. Section 2.1). Improving efficiencies and pushing innovation towards a circular economy will affect societal, economic and environmental issues. Multiple stakeholders (c.f. Table 2) stated more general needs for economic growth (13), technological development (14), as well as material valorization (15), and land reclamation (16). Industrial actors expressed three additional needs: the installation of ELFM pilot projects at industrial scale to push implementation (17) and flexibility in ELFM valorization routes (18).

At a project level, the effects of economic development (13) are more likely to have a local to regional range, while technological development (14) is more likely to reach out further. The economic development highly depends on market developments that can affect private cost and benefits through rising salaries and revenues, for example. Rising salaries, on the other hand, generate secondary income effects that can have a notable impact at local levels. In contrast, technological development also has societal costs and benefits that can include research funding or risk reduction through environmental improvements. Moreover, technological development heavily influences the choice of valorization route for ELFM projects, which again is also dependent on market developments. Industrial actors are mainly motivated to push technological development to improve profitability, whereas institutional actors also stated potential (geo)strategic advantages.

The need for material recuperation (15) was expressed by the European governmental actor and the operators. Mainly construction materials are considered in this context, as the share of metals is usually rather small and the fine fraction, containing mainly biomass and plastics, is difficult to recycle (c.f. Section 2.1). The European Union, being also a well-established producer of construction materials, would further increase its resource independence. Impacts would reach from a local to regional level as the economic feasibility of transport ranges for construction materials is limited. Furthermore, this need is closely related to avoided impacts (6) and technological advances (15) could potentially yield environmental benefits.

Land reclamation (16) plays an important role for institutional actors as well as operators. Impacts on sustainability highly depend on the after-use, but potential effects are mainly limited to a local level. Societal costs and benefits can be monetary and non-monetary: changes in housing prices or health improvements through the creation of recreational land, for example. This need is closely related to Need 8.

The need for ELFM pilot-scale projects for proof of principle (17) was expressed by the operators. It implies societal costs through the participation of public research, but also creates private costs for research and development at relatively high economic risks. The operators further expect to use these pilot projects as vehicles for knowledge distribution to push general ELFM implementation. The range of effects of this stakeholder need is therefore considered local to supranational.

The need for flexibility in valorization routes (18), also expressed by the operators, is perceived as a measure to react to short- and mid-term market developments. It also challenges technological development and research to take these flexible valorization routes into account. Effects manifest mainly at local to regional levels and impacts are mainly economic and environmental.

4.5 Uncertainty

The following section treats the five types of uncertainty. Complying with stakeholder needs should generally lower uncertainty about ELFM. Nonetheless, the implementation of some stakeholder needs could also have increasing effects. Figures 4 to 8 show how the different needs affect the five types of uncertainty, arranged by the four categories. The direction of effects can be positive (+), meaning an increase in uncertainty, negative (-), i.e. a decrease in uncertainty or (+/-) unclear, depending on contextual factors.

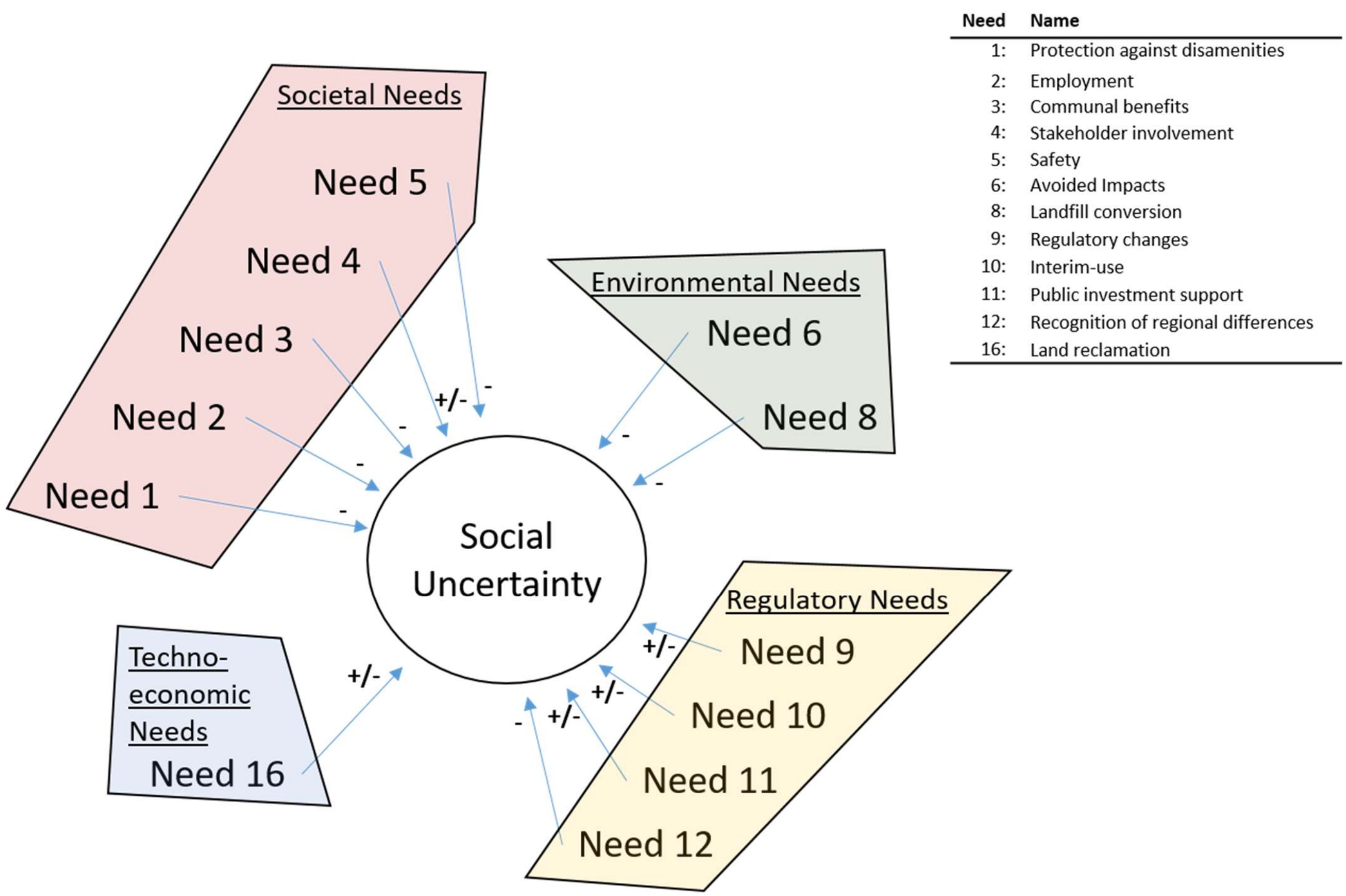


Figure 4: The interaction of stakeholder needs with social uncertainty.

Social uncertainty is generally expected to lower with the compliance of societal needs, and thus, increase public acceptance. However, involving stakeholders (4) and increasing knowledge distribution about ELFM could motivate ELFM supporters similarly as ELFM opposition and the directional effects of this need on social uncertainty are unclear. Complying with environmental needs is expected to lower social uncertainty because of the dominant role environmental benefits from ELFM play for community and institutional actors. Through the implementation of a regulatory framework for ELFM, certainty about processes and procedures could be created for all stakeholders, preventing public and industrial fears and lowering social uncertainty in the long run but social uncertainty could raise short-term, due to public discussions and legal procedures leading to the implementation of regulations. The only techno-economic need affecting social uncertainty is land reclamation (16) but effects are unclear and highly depend on the after-use.

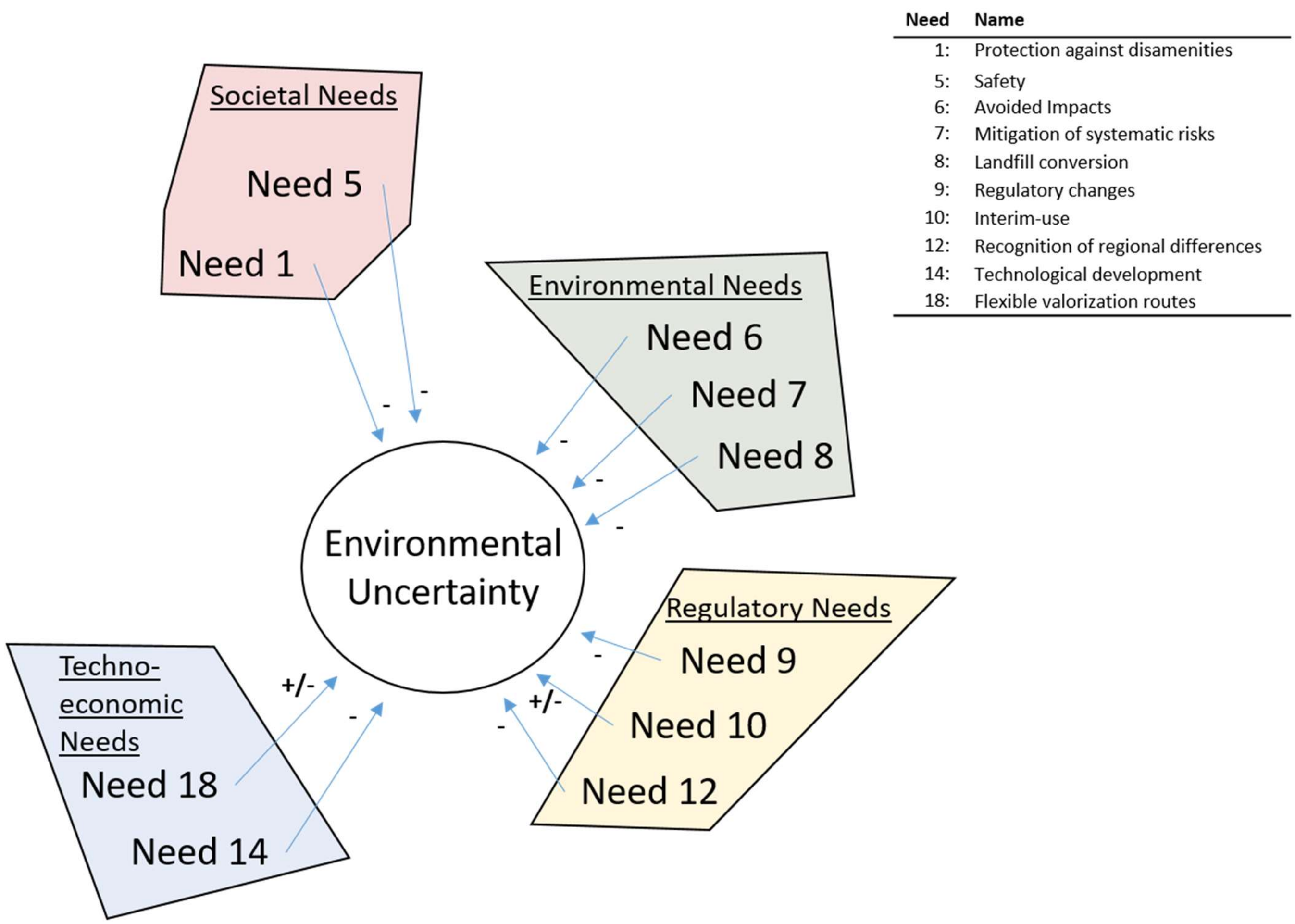


Figure 5: The interaction of stakeholder needs with environmental uncertainty.

Environmental uncertainty is expected to lower with overall creating environmental benefits through ELFM. Protecting community actors from disamenities (1) and increasing the safety of ELFM operations (5) (e.g. handling of hazardous waste) should affect environmental uncertainty similarly, as both needs are closely related to preventing emissions. Implementing a regulatory framework (9), taking regional differences into account (12) could further lower environmental uncertainty in a similar way as social uncertainty. Integrating an interim-use phase into ELFM regulation, however, could also create more environmental uncertainty, depending on its implementation and time-dependent, dynamic effects. Material valorization (14) is closely linked to avoided impacts, whereas flexible valorization routes (18) could potentially create environmental risks and opportunity costs due to trade-off considerations with economic factors.

Need	Name
1:	Protection against disamenities
5:	Safety
7:	Mitigation of systematic risks
9:	Regulatory changes
10:	Interim-use
11:	Public investment support
12:	Recognition of regional differences

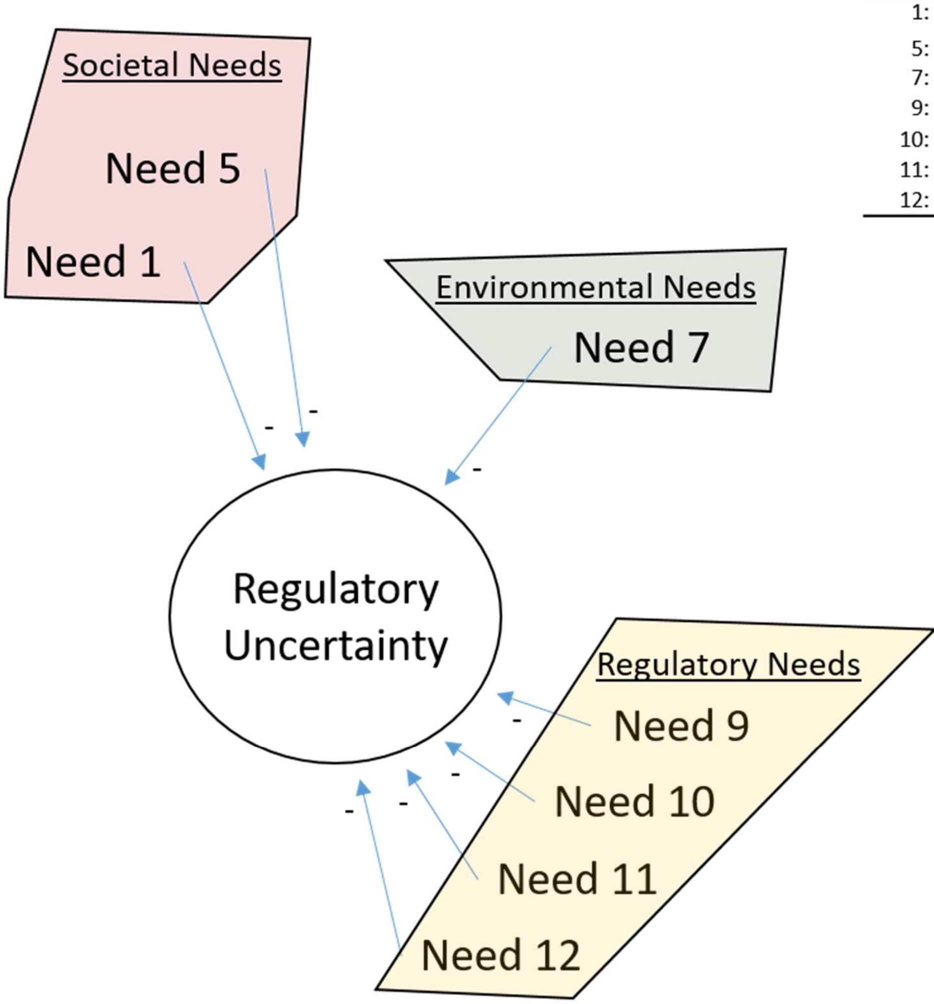


Figure 6: The interaction of stakeholder needs with regulatory uncertainty.

Regulatory uncertainty should generally lower with the implementation of ELFM regulation (9-12). The integration of community needs (1 and 5), to some extent, could additionally lower regulatory uncertainty and increase public acceptance. Nonetheless, as no regulatory framework exists, mitigating systematic risks (7) could increase uncertainty, even though generally ELFM is compliant with current legislation (c.f. Section 2.3). Building infrastructure on top of a closed landfill bares more risk if it is unclear if that landfill might have to be mined in the future due to flood risks, for example.

Need	Name
2:	Employment
4:	Stakeholder involvement
10:	Interim-use
13:	Economic growth
14:	Technological development
15:	Material recuperation
16:	Land reclamation
17:	Pilot projects
18:	Flexible valorization routes

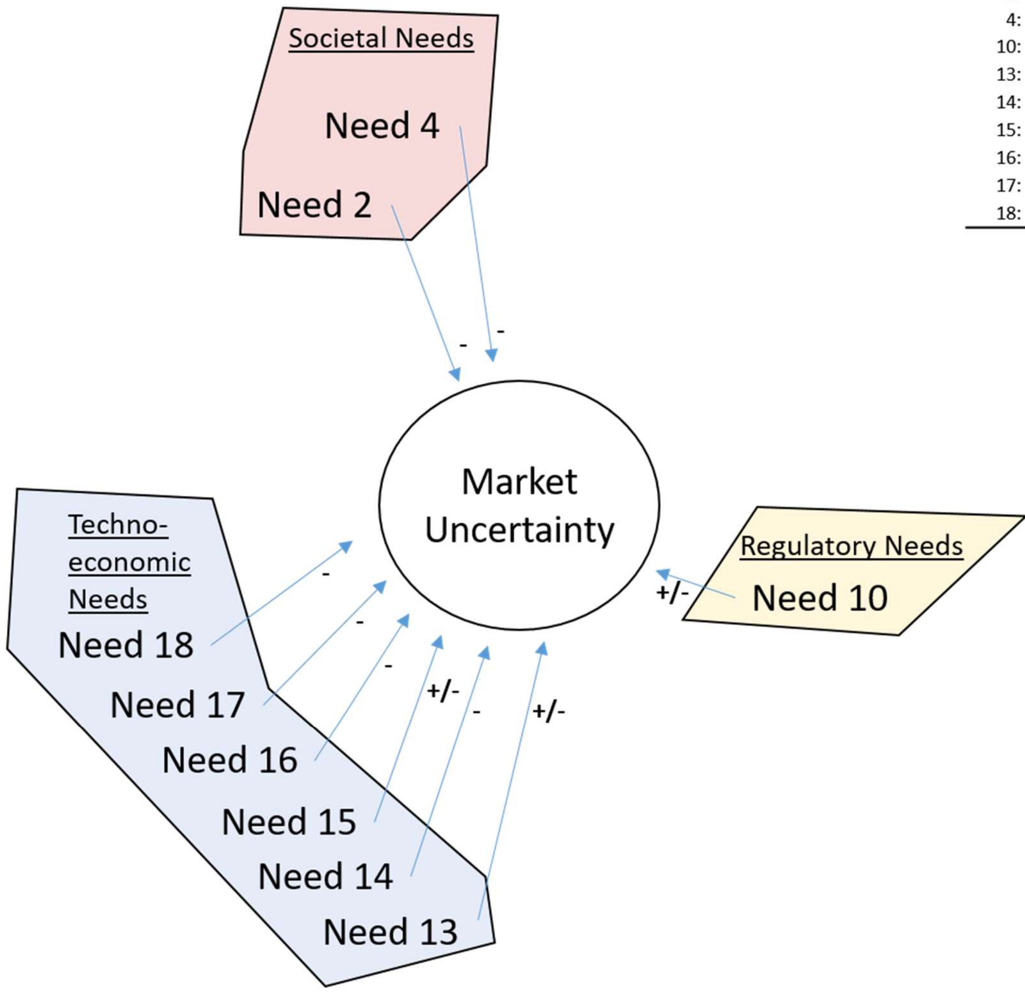


Figure 7: The interaction of stakeholder needs with market uncertainty.

Market Uncertainty is predominantly affected by techno-economic needs. While complying with most of these needs should lower market uncertainty, economic growth (13) and technological development (15), and with it, potential changes in the dynamics of markets, could also increase uncertainty. Creating employment opportunities (2) is likely to interact with market uncertainty through secondary income effects but effects are unclear. Integrating stakeholder, on the other hand, should lower market uncertainty through the distribution of information to potential investors and industrial actors. Integrating an interim-use phase (10) would also interplay with market uncertainty since the optimal time to mine a landfill depends on the marketability of an ELFM project's products.

Need	Name
15:	Material recuperation
17:	Pilot projects
18:	Flexible valorization routes

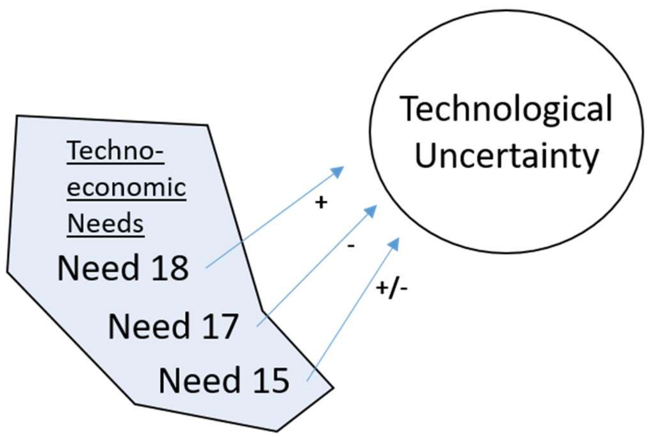


Figure 8: The interaction of stakeholder needs with technological uncertainty.

Technological uncertainty is the only type of uncertainty not affected by other needs than techno-economic ones. Naturally, technological development (15) is affecting uncertainty about it. Effects are, however, unclear. ELFM could potentially benefit from technological advances but also create barriers for the concept through the development of alternatives for ELFM products and thus increasing competition. ELFM pilot projects (17) should reduce technological uncertainty by creating more certainty about quality standards of ELFM products and increased learning effects. Meeting the need for flexibility in ELFM valorization routes (18) makes plant and process development more challenging and more options would most likely increase technological uncertainty.

5 Discussion

Through a broad stakeholder integration, several stakeholder needs were identified and analyzed. This anticipatory approach has shown different perspectives, as well as effects on ELFM implementation and various stakeholder groups. The spatial distribution of the effects of ELFM implementation highlights the potential for conflicts in public acceptance and should be considered in future research. Moreover, research is needed to further structure ELFM related uncertainties. Different types of uncertainties are present throughout all stakeholder need categories, and half of all stakeholder needs, i.e. 9 out of 18, refer to all three dimensions of sustainability. This emphasizes the need for an integrated assessment model and further method development for ELFM.

While the integration of stakeholders, in practice, is well established for the Remo landfill (c.f. Ballard et al., 2018), this is rarely reflected in the case-specific literature. Technological, environmental and market uncertainties are analyzed to some extent by means of sensitivity analyses (c.f. Section 2.2) but, similarly to suggestions from other ELFM studies, indicate that more research is needed. Overall, an integrated assessment method is lacking, although combined environmental and economic assessments (e.g. Danthurebandara et al., 2015) are performed, and societal perspectives are, to some extent, integrated through the monetization of (environmental) externalities or rankings (c.f. Section 2.1). Societal needs (e.g. Need 2 and 5), however, are rarely addressed. Need 1, protection against disamenities, is only addressed in the context of biodiversity by installing noise mitigation facilities for the protection of wildlife (c.f. De Vocht et al., 2011). Environmental needs are addressed. Avoided impacts (6), for example, are considered in LCA and economic studies, but results vary due to different methodological choices (c.f. Section 2.1). Techno-economic needs are better incorporated into ELFM research at Remo, as regional economic potentials are assessed, and different valorization routes are reflected in various ELFM scenarios (c.f. Section 2.1). It should be noted that, in contrast to the importance given to it in the interviews, land reclamation (16) constitutes a relatively low economic benefit for the Remo case (c.f. Van Passel et al., 2013) but can have a significant (positive) environmental impact (c.f. Danthurebandara et al., 2015). Regulatory needs are also not reflected, although considering public investment support (11), as well as an interim-use phase (10), would have a noticeable influence on the scenario building, not only for the Remo case.

Generally, prioritizing environmental factors differently from economic or societal ones can lead to changes in valorization routes, and thus affects scenario building. Costs related to public acceptance (e.g. for lobbying) have to be taken into account, as well as non-monetary benefits from the integration of stakeholder needs, like changes in uncertainties. Related factors could be integrated into the building of scenarios, including legal costs in case of low acceptance due to non-compliance with other factors like protection against disamenities (1). A more differentiated scenario building would reduce social, regulatory and technological uncertainty, and, in combination with the analysis of related costs and benefits, result in a clearer picture of possibilities for ELFM implementation, thus increasing the quality of decision support for ELFM stakeholders.

Another important issue that has been neglected by ELFM research so far is that of time-dependent factors. The need for flexibility of ELFM valorization routes (18), similarly to public investment support (11), greatly depends on the consideration of market developments and generates research and opportunity costs for achieving this flexibility. Is the area of a closed landfill used for electricity generation through solar panels, for example, but planned ELFM operations would focus on material valorization, then the optimal time to invest depends on the development of electricity and material prices. Environmentally, negative impacts from ELFM operations (c.f. Danthurebandara et al., 2015; Winterstetter et al., 2015) are contradicting the relatively mild impacts of a “business as usual” or “do nothing” scenarios. However, ELFM’s contribution to the mitigation of long-term environmental risks of landfills through waste removal plays an important role for stakeholders, although in reality these risks should be evaluated case specifically, and the challenge of assessing this topic still has to be taken on by ELFM research (Sauve and Van Acker, 2018), also depending on LFG emissions and their behavior over long timeframes. Research in this area is needed to reduce environmental uncertainty. Including dynamic modeling into ELFM assessment would further lower market-related uncertainties and could be made possible through the combination of risk assessment with LCA, for example, or the use of real options theory.

Integrating intra- and interdimensional relations and trade-offs in ELFM assessment is a difficult task. Further analysis of the interaction between economic, environmental and societal factors is needed. Enhancing the flexibility of ELFM valorization routes (18), for example, could generate environmental opportunity costs when considering trade-offs with the economic dimension. Due to external factors (e.g. markets), a valorization route (WtE vs. WtM) could be chosen that promotes a sub-optimal environmental performance but yields higher profits. These environmental opportunity costs also imply societal impacts whose prevention often implies private economic costs. Often, monetization, as a form of normalization of impacts, is used to resolve these trade-off dilemmas. However, to actually compare non-monetary impacts on the basis of scenarios, monetization is not immediately necessary. Rankings can be created and qualitative research can help to determine priorities, underlining the importance of stakeholder integration and the development of an anticipatory approach. A beneficial side effect of more qualitative research in the field of ELFM would be knowledge accumulation and with it the reduction of social uncertainty.

Another challenge in assessing ELFM comes to light considering the distribution of societal impacts. While an ELFM project can have an overall socio-environmental benefit through the reduction of global GHG emissions, local emissions (e.g. particulate matter) might increase due to ELFM operations. This can imply monetary and non-monetary costs in one location whereas non-monetary benefits are usually generated at another location. The integration of these different spatial distributions into ELFM research is not an easy task and deserves more scientific attention. This would lead to a more granular differentiation of ELFM impacts and contribute to a sensible ELFM implementation. It could further lead to a reduction in social and regulatory uncertainty and a mix of qualitative and quantitative research methods is necessary.

6 Conclusions

Conducting stakeholder interviews has proven to be a valid method to evaluate stakeholder needs. Although some stakeholder needs have been addressed in the assessment of the Remo case, the study shows that an integrated assessment method is needed, and implications for ELFM research can be generalized even though specific stakeholder needs might vary amongst different case studies.

The anticipatory approach has uncovered several research gaps and important factors affecting ELFM implementation. Numerous parameters, affecting the assessment of different sustainability dimensions in ELFM, were derived. However, more integrated research is needed to ensure that results are complete and sound. The stakeholder needs were categorized into societal needs, environmental needs, regulatory needs, and techno-economic needs. Societal and techno-economic needs dominate in absolute numbers but the interviews revealed that depending on the stakeholder class, a different emphasis is given to the three sustainability dimensions and environmental needs are perceived as highly important by institutional and community actors.

It is important to note that private economic structures of ELFM projects are affected through the integration of these stakeholder needs, and time and market dependent variables should be considered in the future. Furthermore, more attention should be given to the scenario building in ELFM assessment. ELFM assessment has to find a way of dealing with inter-dimensional trade-offs. This includes the assessment of economic and environmental opportunity costs when comparing different scenarios or assessing the combination of different valorization routes.

To further foster the societal assessment of ELFM projects an integrated method is needed. Next steps should include the following: (i) refine economic and environmental assessment methods, (ii) closely analyze socio-economic costs and benefits of ELFM, (iii) find indicators for societal impacts and (iv) integrate the distribution of impacts into ELFM assessment together with ELFM stakeholders.

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9 Appendix

The appendix shows the main questions developed for the interview guide. Due to limitations in time and slightly different foci of each semi-structured interview, not all interviewees were asked all of the questions and follow-up questions varied, depending on the given answers.

1. What is a landfill to you?
2. Can you, in general, describe what advantages and/or disadvantages having landfills comes with?
3. When you think about the REMO site, do you have positive or negative associations?
4. Are you familiar with the concept of LFM/ELFM?
5. Do you think LFM/ELFM should be done?
6. What projects about LFM/ELFM are you involved with?
7. What are the main advantages/opportunities you see in LFM/ELFM projects?
8. According to you, which are the main environmental benefits of LFM/ELFM?
9. What main disadvantages/risks do you see with the realization of an LFM/ELFM project?
10. According to you, which are the main negative environmental impacts/risks of LFM/ELFM projects?
11. According to you, which are the main challenges for the realization of LFM/ELFM projects?
12. What economic drivers and/or barriers can you identify?
13. What regulatory instruments do you know affecting LFM/ELFM projects?
14. Where do you see markets for the products/outcomes of LFM/ELFM?

15. What societal challenges do you expect/have you experienced in LFM/ELFM projects?
16. According to you, which are the most influential actors when it comes to the planning and realization of LFM/ELFM projects?
17. Who do you think is/should be responsible for regulating and/or communicating LFM/ELFM?
18. How do/does the authorities/your institution deal with uncertainties concerning LFM/ELFM projects?
19. How happy are you with the role of institutions/authorities when it comes to LFM/ELFM?