Measuring societal impact of standards

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PROJECT REPORT

Measuring societal impact of standards

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This document reports the results of the research project “Measuring Societal Impact of Standards”. The project was jointly financed by the XXM Partners, being the national standards bodies of:

- Austria, (Austrian Standards International, ASI);
- Denmark (Danish Standards, DS);
- Finland (Finnish Standards Association, SFS);
- The Netherlands (Royal Netherlands Standardization Institute, NEN);
- Norway (Standards Norway, SN);
- Sweden (Swedish Institute for Standards, SIS).

The project was jointly carried out by researchers of Eindhoven University of Technology and Rotterdam School of Management, Erasmus University. The report is partly based on data that were collected by students of Rotterdam School of Management, Erasmus University under the research team’s guidance. The project funders did not influence the contents of this document, and the views expressed in it are those of the research team.

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Executive summary

Society faces existential challenges, such as global warming, demographic change and digital innovations. Standards help solving problems and reaping opportunities. They have long been recognised as important, from technological, business, and economic perspectives, but clear evidence about their societal impact is still missing.

Against this background, the XXM Partners commissioned this project to get a clearer view of how standards impact society. The project was carried out by researchers from Eindhoven University of Technology and Rotterdam School of Management, Erasmus University between November 2021 and November 2022. We conducted a pre-study of 48 standards, reviewed academic literature on standards' impact and its measurement. We carried out eight in-depth case studies of particular standards with 86 expert interviews, relevant documents, and other sources. In doing so, we reached all five goals that were agreed in the project contract:

Goal 1: Overview over dimensions of standards impacts

Societal impact has many dimensions, which relate, e.g., to public health, education, or the environment. Our literature review identified the 17 United Nations Sustainable Development Goals (SDGs) as the most suitable framework for our project. The SDGs are goals, agreed upon in global consensus, on which society should focus and improve. A growing global movement has formed around them to address societal challenges.

In a pre-study, we conducted desk research to explore *potential* impacts of 48 standards. They cover the breadth of subject areas, and include standards with societal, environmental, technical and/or business purposes. We find that these standards can be linked to all SDGs. Often one standard affects multiple SDGs, going beyond intended impacts.

Goal 2: Overview over scientific literature on standards' impacts

Standards are important for society. This is widely recognised in academic literature. However, there is relatively limited research on *how* they impact society. Most of this limited research focuses on two standards: ISO 9001 (quality management systems) and ISO 14001 (environmental management systems). Our review reveals a research focus on business/economic (both standards) and environmental (ISO 14001) impacts. Some evidence exists on non-environmental societal impacts (e.g., workplace safety), but this remains limited.

We extended our review to other fields, especially addressing best practice for impact measurement. We compared multiple approaches, selected the Logic Model for understanding impact, and adapted it to standards. This model helps understand impact by tracing it in five steps: (1) inputs (including standards), (2) activities for standard implementation, (3) outputs (a situation reflecting what a standard prescribes), (4) outcomes (changes for stakeholders), and eventually (5) long-term impact.

Goal 3: Evidence of standards' societal impacts – empirical research

Under the project team's guidance, master students carried out eight in-depth studies in Norway (two studies), Sweden (two studies), Finland (two studies), Denmark and Austria. Standards were selected in consultation with the XXM Partners. They cover a broad range of

important areas, e.g., greenhouse gas (GHG) emissions reporting (ISO 14064-1), clinical trials for medical devices (ISO 14155), and information security management (ISO 27001).

Our studies led to findings about (1) specific societal changes caused by the investigated standards, (2) what drives standards' impacts in general, and (3) measuring standards' impact (see Goal 4 below).

Findings about standards' specific societal changes

Two standards in our study are particularly successful in creating positive impact:

- *EN 16516* (emissions of construction products into indoor air) promotes the availability of low-emission construction products, thereby contributing to healthy indoor air.
- *ISO 14155* (clinical investigations for medical devices) contributes to safer clinical trials and availability of innovative medical devices for patients.

In the other cases, we observe strong potential for positive societal impact. However, this is not achieved, e.g., due to standards not being implemented at large scale, not meeting potential users' expectations, and/or competing with other standards. In two cases (*ISO 14064-1*, GHG emissions accounting; *ISO 14044*, life-cycle assessment), foreseeable abuse of the standard may even provide opportunities for greenwashing.

All investigated standards have broader (potential) impacts on the SDGs than identified by ISO. E.g., ISO 14155 does not only contribute to SDG 3 (*"Good Health and Wellbeing"*), but also to SDG 9 (*"Industry, Innovation and Infrastructure"*) and the institutional aspect of SDG 16 (*"Peace, Justice and Strong Institutions"*).

Findings about drivers behind standards' impacts: importance of their ecosystems

All investigated standards are deeply embedded in their ecosystems.[1] A remarkable finding concerns the large extent, to which (mis)alignment with this context drives their impact. This also makes it challenging to isolate the standard's impact from that of its entire ecosystem.

Where we observed positive impact, this was largely due to a standard serving a clear purpose in its ecosystem (e.g., meeting market needs, supporting certification, alignment with regulatory requirements). In the cases where potentials for positive impact have not yet been realised, our data show how this is driven by misaligned ecosystems and standards. We have recommendations for how to address this (see Goal 5 below)

Goal 4: Applied methodology for demonstrating societal impacts

In the course of the project, we developed a methodology for measuring standard's societal impacts. It consists of a six-step process, which is based on four essential frameworks/tools:

1. Stakeholder analysis,
2. A checklist for analysing a standard's ecosystem,
3. The logic model for standards,
4. The SDGs as a framework for classifying impact.

[1] Based on Bogers et al. (2019), we define an ecosystem as an interdependent network of actors jointly creating value. In many ecosystems, standards have an important function for this joint value creation, e.g., by coordinating these actors' activities.

We recommend this methodology for systematically studying further standards' impacts.

Goal 5: Recommendations to National Standard Bodies (NSBs)

Our results have clear implications for the XXM Partners, ISO/IEC, CEN/CENELEC, and their members. Based on these implications, we provide recommendations on (1) communicating standards' impacts to policymakers and other stakeholders, and (2) enhancing standards' positive impact. Section 9.5 (p.102) specifies these recommendations in detail.

Communicating standards' impact

- *To policymakers:* Emphasise standards' functions as essential instruments for change in their respective ecosystems.
- *To other stakeholders:* Focus on standards' contributions to the SDGs, while acknowledging that the full potential is not yet achieved.
- *Ensure standards' inclusion in frameworks for measuring societal impact:* Engage in dialogue with the impact measurement community. Ensure that increasingly influential approaches to measuring societal impact include standards. This would support clearer communication about standards' impacts *and* contribute to frameworks' accuracy.

Enhancing standards' positive impact

- *Already address societal impacts during the standardisation process.* We provide two tools, which may be used for this.
- *Improve standards' relevance and quality in line with their ecosystems' expectations* (positioning standards relative to competing and/or complementary standards, clarity of requirements, quality of translations, withdrawing unused standards).
- *Need for future research* in six directions: (1) Studies at the level of standard families and/or ecosystems. (2) Large-scale replication. (3) Understanding standard competition. (4) Reflecting ongoing developments in impact measurement. (5) Effects of societal change on standards' role in society. (6) Starting from the "grand-societal challenges".

Conclusion

Our work makes a novel contribution to knowledge about standards' impacts. By doing so, we offer concrete insights, which the XXM Partners can use in communicating the benefits of standards. We also identify key factors affecting standards' societal impacts, and offer tools and methods that are relevant for practitioners and researchers alike. The XXM Partners can use these insights in their work to further maximise standards' value to society, and limit any potential negative effects.

1 Introduction & project goals

Society faces a number of "grand-societal challenges", such as global warming and digital innovations which contribute to inequality and social disruptions. Policy initiatives, like the United Nations Sustainable Development Goals (SDGs) and the EU's green, digital and resilient economy, aim to address these challenges. Standards (and national standard bodies – NSBs) already have strong impact on addressing such societal challenges, e.g., by "Harmonised Standards" supporting many European Directives and Regulations. Given the increasing focus on these challenges in contemporary debates, standards and NSBs are likely to be called upon for an even greater contribution in the future.

However, unlike standards' economic and business impacts, their societal impacts have not been researched in a systematic way. Available evidence is fragmented and often anecdotal. This makes valid and reliable general statements about societal impacts difficult. The same fragmentation applies to research methods. In order to provide a sound basis for future systematic research on the topic, the XXM Partners funded this research project with the aims (1) to provide an overview of societal impacts, and (2) develop and test a tool for assessing societal impacts of standards (see Section 1.1 for more detail on the agreed aims and objectives).

We (Dr. Paul M. Wiegmann, Assistant Professor, Eindhoven University of Technology, project leader; Prof. Dr. Ir. Henk J. de Vries, Rotterdam School of Management, Erasmus University; Dr. Doyoung Eom, Postdoc, Eindhoven University of Technology; see Appendix 11.1 for more information) have been carrying out this project from November 2021 to October 2022. We were supported by nine master students and 48 bachelor students from Rotterdam School of Management, Erasmus University (see Chapter 2 for details).

1.1 Aims, objectives & deliverables of the project

The project has been funded by the XXM Partners, who briefed the research team to build "in a scientific way empirical evidence on the societal impact of standards/standardisation" as "the most important and overall study objective". Based on this briefing, the agreed project proposal (Version 2021-06-14) defined the following goals:

1. Provide an overview of dimensions of societal impacts of standards;
2. Provide an overview of scientific literature on impacts of standards;
3. Develop cases that provide evidence of societal impacts of standards;
4. Develop a methodology to demonstrate the societal impacts of standards;
5. Propose how the methodology/test results can be transferred to regular use by the funding NSBs.

To achieve these goals, the agreed project proposal defined five deliverables for the project team (see Appendix 11.2 for the precise description of each deliverable, as included in the agreed project proposal):

1. Literature review
2. Overview over cases of standards and their societal impacts
3. Assessment method

4. In-depth studies of standards and their societal impacts
5. Reporting

This document reports how the project has achieved each deliverable and therefore met its goals, as outlined in Section 1.2.

1.2 Structure of the project report

The report is structured in line with the logical flow on which we developed each deliverable outlined in Section 1.1 during the project. Each deliverable is addressed by one or two chapters in this report. Table 1 on p.9 shows to which deliverable(s) and goal(s) each chapter contributes. Altogether, the report contributes to Deliverable 5 (Reporting).[2]

[2] In addition to this report, there were multiple moments when we presented in-between results to the XXM Partners, in line with the reporting deliverable. See Appendix 11.3 for an overview.

Table 1: Report chapters' contributions to the project deliverables and goals

Chapter	Deliverable	Goal(s)
1. Introduction & project goals	5. Reporting	
2. Project design & methodology	5. Reporting	
3. Theoretical foundations of the research project	1. Literature review	1. Provide an overview of dimensions of societal impacts of standards. 2. Provide an overview of scientific literature on impacts of standards. 4. Develop a methodology to demonstrate the societal impacts of standards.
4. Studies about ISO 9001's and ISO 14001's impacts	1. Literature review	2. Provide an overview of scientific literature on impacts of standards.
5. Pre-study: dimensions of standards' potential impacts	2. Overview over cases of standards and their societal impacts	1. Provide an overview of dimensions of societal impacts of standards.
6. In-depth case studies: findings	4. In-depth studies of standards and their societal impacts	3. Develop cases that provide evidence of societal impacts of standards.
7. In-depth case studies: cross-case analysis	4. In-depth studies of standards and their societal impacts	3. Develop cases that provide evidence of societal impacts of standards.
8. Applied methodology for measuring impacts	3. Assessment method	4. Develop a methodology to demonstrate the societal impacts of standards. 5. Propose how the methodology/test results can be transferred to regular use by the funding NSBs.
9. Conclusions	5. Reporting	5. Propose how the methodology/test results can be transferred to regular use by the funding NSBs.

2 Project design & methodology

As outlined in Chapter 1, our project consists of a number of elements that relate the deliverables and goals of the agreed project report. Section 2.1 summarises the core challenges and key questions and how we structured the project around them.

In resolving these challenges, we relied both on theoretical academic knowledge and on empirical data. Section 2.2 outlines the methods of the project's empirical parts: a pre-study of standards potential impacts, and a small number of in-depth case studies of specific standards' impacts.

2.1 Project process: core challenges and key questions

To achieve the aims of the agreed project proposal, we structured the project around six interrelated core challenges and associated key questions. Figure 1 summarises them and shows how the challenges are related (e.g., solving Challenge 6 relied on solving both Challenge 3 and Challenge 4).

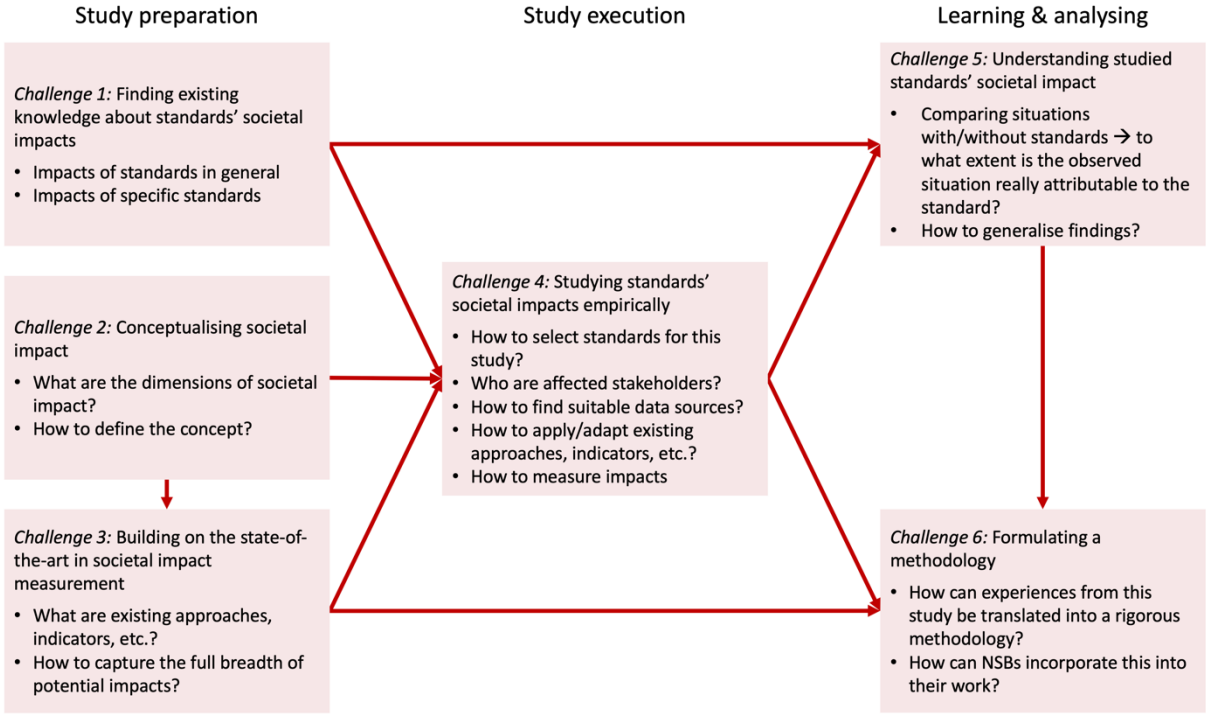

Figure 1: Process challenges and key questions in the project

We resolved each challenge with theoretical, empirical, logical, and/or conceptual approaches. Table 2 on p.11 shows the approach(es) we used for each challenge, and the chapters reporting the results. Altogether, this project design means that we provide (1) a good indication of how standards in general may impact society, (2) specific evidence of the societal impacts of the standards studied in the in-depth case studies, and (3) clear guidelines to researchers and practitioners wishing to identify the impacts of further standards not covered by our study.

Table 2: Methods used for resolving process challenges in the project

Challenge	Method(s) used for solution	Chapter(s)
1	Theoretical: literature review of standards' impacts	3 & 4
2	Theoretical: literature review of societal impact definitions Empirical: pre-study of standards' potential impacts	3 5
3	Theoretical: literature review of societal impact measurement methods Conceptual: applying insights from literature to standards (providing the foundations for solving Challenges 4, 5, and 6)	3
4	Empirical: in-depth case studies of specific standards' impacts	6
5	Empirical: in-depth case studies of specific standards' impacts Empirical: cross-case analysis across in-depth case studies Logical generalisation beyond studied cases	6 7 9
6	Conceptual: methodology development	8 & 9

2.2 Methodology of empirical project

The project contains two empirical parts. Section 2.2.1 explains the methodology of our pre-study, and Section 2.2.2 outlines the methodologies used for our in-depth case studies.

2.2.1 Standards' potential impacts: Pre-study

The pre-study aimed to gain an as-complete-as-possible overview over how standards can affect society. To achieve this objective, we reviewed 48 standards to identify how they may be relevant for society. Below, we explain how we selected the standards to be included, and the procedures for deriving their expected societal impacts. The results of the pre-study can be found in Chapter 5.

Selection of standards

To achieve the pre-study's objectives, we aimed for a set of standards, which (1) covers the diversity of standards (e.g., in terms of technical fields, functions of standards, and national/international scope) and (2) includes standards with substantial societal impact. We used a three-step procedure for sampling standards that meet these criteria:

1. We first selected the best-selling standards (covering national, European, and global standards) from NEN's ranking of standards' sales (plus the top-three downloads of freely available standards) in the years 2016-2020. This was based on the assumption that standards being sold/downloaded more often would be implemented more often and therefore have more substantial impact.
2. We next verified the variety of the standards selected in the previous step in terms of subject matter, using the International Classification for Standards (ICS) (ISO, 2015),

This showed the sample to be one-sided, with most standards relating to one of three ICS main groups.[3]

3. Subsequently, we identified a suitable standard from each missing ICS main group. Based on the assumption that standards mentioned in *ISO Focus* are important for their respective fields and thus they likely to be particularly impactful, we selected standards that we found there.

We identified 48 standards meeting these criteria (29 international standards, six European standards, 13 national standards; see the full list in Appendix 11.4), which form the basis for the pre-study.

Identification of potential societal impacts

In line with the agreed project proposal, Bachelor students participating in the minor "Responsible Innovation" in September/October 2021 supported the pre-study. Each one of the 48 standards was assessed individually for its potential impacts by a student. In doing so, they were guided by a member of the research team (Prof. Dr. Ir. Henk J. de Vries), who provided instructions and feedback.

Students identified potential impacts based on the full standard document, further secondary sources identified by them (where available), and their own logical reasoning. Based on this information, each student first identified his/her standard's stakeholders and their expected stakes, using a systematic method. Subsequently, they identified how each stakeholder is likely to be affected if the requirements described in the standard are implemented. Based on this, students provided an overview of each standard's societal dimensions and classified them in terms of the United Nations Sustainable Development Goals (SDGs, see Section 3.2.1). They followed a three-step process for identifying impacts:

1. *Identifying primary impacts:* Based on the scope and introduction of each standard, the students identified its main purpose and derived impacts resulting from achieving this main purpose. In line with the project purpose, we only included societal impacts and excluded those that are 'purely economic'.
2. *Identifying secondary impacts:* Based on the introduction and other chapters of each standard, the students identified additional changes likely to result from implementing the standard, which do not stem from achieving its main purpose. These were translated into additional impacts and linked to the SDGs.
3. *Identifying impacts related to other SDGs:* While Steps 1 and 2 took the standard as a departing point, Step 3 started from the SDGs. For each SDG, students reflected whether there may be additional relevant effects resulting from 'their' standard.

Based on the results achieved by the bachelor students, a master student and a member of the research team (Prof. Dr. Ir. Henk J. de Vries) independently verified findings and adjusted the identified impacts if needed. The corrected results were analysed as shown in Chapter 5.

[3] 13 standards were classified in *"03 Services. Company organisation. Management and quality. Administration. Transport. Sociology"*, twelve in *"91 Construction materials and building"*, and eight in *"13 Environment. Health protection. Physical phenomena"*. Many standards are classified in multiple categories.

2.2.2 *In-depth case studies of specific standards' impacts*

The in-depth case studies analyse a small number of standards' societal impacts in detail.[4] Below, we outline how the cases for the in-depth studies were selected, and explain how the studies were carried out and how the results were incorporated in this report. The results of the in-depth studies can be found in Chapters 6 and 7.

Selection of standards for in-depth analysis

We aimed to select cases that would (1) cover the variety of standards to such an extent that we could observe a range of impacts, but also (2) be comparable enough to allow a cross-case analysis. To achieve this aim, we selected cases based on a theoretical replication approach (Yin, 2009). We identified three dimensions which are likely to affect a standard's societal impact a-priori: (1) whether it was developed with a societal purpose in mind or not, (2) whether it concerned a niche- or a mainstream technology, and (3) which economic function(s) the standard addresses.[5]

Based on these criteria and practical considerations (e.g., access to data), the XXM Partners nominated standards for inclusion in our study. We selected the final sample of standards out of the nominated cases. See Table 3 for an overview over the standards studied (the table also indicates which XXM Partner nominated which standard).

Table 3: Overview over in-depth case studies

[M]: Measurement [Q]: quality and safety [C]: compatibility [F]: focus	**Niche technology**	**Mainstream technology**
Societal purpose	ISO 17088: compostable plastics [M, Q], Sweden	ISO 22397: societal security [Q], Austria[6] ISO 14155: clinical studies of medical devices [Q], Finland ISO 14044: life-cycle assessment [M], Norway ISO14064-1: greenhouse gas measurement [M, Q], Sweden
Non-societal purpose	Hydrogen [Q, C, F], Netherlands[7]	EN 16516: indoor air emissions of construction products [M], Finland ISO 19650-2: building information modelling [C], Norway[6] ISO 27001: information security management [Q], Denmark

[4] The agreed project proposal aimed for five in-depth case studies. We eventually were able to conduct eight studies, of which six resulted in sufficient data for detailed analysis.
[5] We define standards' economic functions in line with Blind (2004), see Chapter 3 for details.
[6] This study is unfortunately incomplete. We present main findings.
[7] The study was not completed due to personal circumstances of the student who was carrying it out. No results related to this case are presented in this report.

Procedure for in-depth case studies

Each in-depth case study was conducted by a master student during an internship at an XXM Partner. All students were guided by two members of the project team, and a supervisor at the standards body. They collected data by interviewing experts in the field of the standard, collecting relevant documents (e.g., the standard itself, regulation relevant for the standard), and reviewing academic literature. Furthermore, questionnaires were sent to each standard's buyers, but these resulted in too low response rates for quantitative analysis. Each student provided a detailed report (see Appendix 11.6), the findings are summarised in Chapter 6.

We took further steps to assure both the quality of the information provided in Chapter 6 and consistency of the underlying data for the cross-case analysis in Chapter 7. Before the students entered the field, we provided them with relevant insights from our literature review (see Chapter 3), such as instructions on how to apply a "logic model" to their cases. After the students reported their findings, we verified each student's individual data analysis, focussing on information that the students had deemed to be relevant. While doing so, we made adjustments to the coding schemes and conclusions drawn from the data, where needed. This gives greater confidence in the empirical support for the findings. Nevertheless, it would have been preferable to re-analyse the entire dataset. Unfortunately, time- and resource constraints prevented us from doing so, meaning that the findings presented in this report may be incomplete on some aspects. We aim to conduct further analysis when preparing scientific publications, and will update this report in case the further analysis reveals new insights that are relevant for this document.

3 Theoretical foundations of the research project: literature review

Chapter 3 reviews literature about standards' general impacts, as well as the state-of-the-art in societal impact measurement.[8] Subsequently, we show how to identify and measure societal impact in the standards context, thereby providing the theoretical underpinnings for the results reported in Chapters 5, 6, and 7, and the methodology described in Chapter 8.

The Chapter is structured as follows: Section 3.1 introduces the "grand societal challenges", and shows how standards can contribute to solving them. Section 3.2 identifies definitions and dimensions of societal impact, drawing on insights from the standardisation and non-standardisation literatures. Section 3.3 reviews approaches for measuring societal impact from different streams of literature. Finally, Section 3.4 takes a step away from the literature to explain how we translated the insights into an approach for standards, which provides the foundations for the rest of the project.

Following this chapter, Chapter 4 reports the results of a second literature review about ISO 9001's and ISO 14001's impacts. While there is only little research concerning standards societal impacts in general, there is a substantial body of literature concerning these two standards' impacts, over which we provide an overview.

3.1 Standards' societal importance

Mankind faces a number of "grand societal challenges", such as global warming, resource scarcity, demographic change, and digitalisation. These challenges require far-reaching changes of values, attitudes and behaviour. This has been addressed by policy initiatives like the United Nations' Sustainable Development Goals (SDGs) and the EU's Digital Single Market. Standards, have been contributing to solving important problems since their inception. They result from standardisation processes, where a variety of stakeholders interact and share knowledge to jointly solve challenging issues. They make these solutions accessible to a broad audience. Standards' importance for addressing societal challenges has been recognised by practitioners (European Commission, 2022a; Krammer, 2000; Valovaya, 2021) and academics (Bekkers, 2018; de Vries, 2019) alike. This role is linked to the effects and functions of standards, which so far have been mainly researched from an economic angle (Blind, 2004; Swann, 2010), but are increasingly being recognised as also spanning into other societal areas, such as environmental protection or health and safety (Brunsson et al., 2012; Garcia et al., 2015; Wickson and Forsberg, 2015; Wijen, 2014).

Standards clearly impact on society, but the exact nature of their effects varies per standard. For example, some standards are specifically aimed at a societal problem (e.g., ISO 37001 aims to limit corruption (ISO, 2022a)), whereas the focus of others lies on technical issues or business opportunities. Nevertheless, also those standards may have implications for societal welfare, e.g., when technical standards formulate requirements for product safety

[8] The chapter is largely based on a conference paper (Wiegmann et al., 2022b) written by the research team in the context of this project.

which help reduce accident-related health issues. These potential societal contributions have also been recognised by policymakers, who are increasingly using standards as a policy instrument to achieve desired societal outcomes. This underlies the role that standards play in the European "New Approach" (see Borraz, 2007; European Commission, 2017a). This has also been a reason for regulators to intervene in standardisation processes where they saw societal interests at stake (see e.g. Wiegmann, 2019a).

Although many cases of standards having a positive impact on society have been described, this does not always apply. Some standards may also have no impact, or even impact society negatively. For example, standards by the International Organisation for Standardisation (ISO) for measuring harmful substances in cigarette smoke have been criticised for underestimating the amounts of these substances. This leads to an inaccurate picture of the health-risks of smoking and potentially even to tobacco products being sold which release more toxic chemicals than the permissible maximum (Hammond et al., 2007; National Institute for Public Health and the Environment, 2018). In conclusion, they can thus be categorised along two dimensions: (1) whether they were intended for a societal purpose or not, and (2) whether they have positive, negative, mixed, or no impact (see Table 4). Furthermore, impacts of a standard may be intended by those who developed it, or may be unintended.

Table 4: Standards classified according to their societal impact

	Has positive societal impact	Has mixed societal impact	Has negative societal impact	Has no societal impact
Standard intended for societal purpose				
Standard not intended for societal purpose				

All of this raises the question what precisely the impact of standards on society is, both at an aggregate level and at the level of individual standards. This has already been studied extensively for standards' economic and business impacts (e.g. Blind and Jungmittag, 2008; de Vries and Verhagen, 2016; Miozzo and Grimshaw, 2005; Wakke et al., 2016; Wüllenweber et al., 2008). Furthermore, both ISO and the United Nations Economic Commission for Europe (UNECE) have initiated attempts to link specific standards to the SDGs (ISO, 2022b; UNECE, 2022). Societal impacts[9] have been addressed extensively in fields like social entrepreneurship and development aid (e.g. Hazenberg and Paterson-Young, 2022; Rawhouser et al., 2019; Vanclay, 2003, 2002; Wood, 1991). However, societal impacts of standards have – to our knowledge – not yet been researched systematically. Available evidence about societal impacts is fragmented and often only anecdotal. Impacts that have been identified are often not measured empirically. Consequently, it remains unclear what

[9] The terms "societal impact" and "social impact" are used as synonyms in literature.

shares of standards have positive, neutral, or even negative effects on society, what these effects are, and what the ratio of intended vs. unintended impacts is.

An important reason for this lack of research is missing *well-founded measurement methods* and tools to assess the societal impact of standards. Such methods and tools are highly relevant for both academia and practice. There is an increasingly lively academic debate around the SDGs, grand-societal challenges, sustainability, and similar topics. A sound academic approach to measuring societal impacts of standards is therefore not only needed to drive the standardisation field forward, but also for linking insights from standardisation to neighbouring fields involved in this academic discourse. Practitioners at SSOs and other parties involved in standardisation may use such methods to measure their work's impact on society. This may help to identify areas where standards can be adapted to generate more positive impact. It can also add credibility to communications about (positive) impact of standards to third parties, such as policymakers. Such measurement methods and tools thus also carry a high level of practical relevance.

3.2 Definitions and dimensions of societal impact

First questions when measuring societal impact of standards concern the definitions and different dimensions of societal impact. I.e.: What is societal impact? How can it manifest itself? What areas need to be considered when measuring it? To answer these questions, we consider both insights from broader non-standardisation literature including how societal impact is defined (Section 3.2.1), and from specific work in the standardisation literature (Section 3.2.2).

3.2.1 Insights from non-standardisation literature

Several streams of literature contain lively discourses about societal impact and its measurement. Out of these, the streams on social impact assessment (SIA), social enterprises (SE),[10] and the triple bottom line include the most relevant insights on definitions and dimensions of societal impact. Below, we define societal impact based on these literature streams, and discuss its dimensions.

Societal impact is a complex concept of which there is a substantial variety of definitions in literature (Hazenberg and Paterson-Young, 2022; Rawhouser et al., 2019). Rawhouser et al.'s (2019) review broadly groups definitions into (1) definitions that define societal impact only in terms of the outcomes generated, and (2) conceptualisations of societal impact that take into account principles and processes in addition to the outcomes. Examples of the first group are Roche's (1999, p. 21) definition of societal impact as "significant or lasting changes in people's lives, brought about by a given action or series of actions" and Schuler and Cording's (2006, p. 540) definition of corporate social performance as "voluntary business action that produces social (third-party) effects." A good example from the latter group is Wood's (1991, p. 693) definition of corporate social performance as "a business organization's configuration of principles of social responsibility, processes of social responsiveness, and policies, programs, and observable outcomes as they relate to the firm's

[10] In the SE literature, societal impact is a major topic of interest because it is considered to be the main measure of social enterprises' success.

societal relationships." Due to our work's focus on standards, rather than organisations, where these types of internal workings do not apply,[11] we follow the first group which views societal impact purely in terms of outcomes and not of organisational processes. Furthermore, in line with examples of standards having different kinds of impact (see Section 3.1), we follow Rawhouser et al.'s (2019, p. 98) call to adopt definitions of societal impact that cover *both* positive and negative impact caused by an activity. Finally, there are challenges related to temporal aspect in conceptualising societal impacts: Considering too short periods may lead to not fully capturing all relevant outcomes, whereas considering too long periods may contribute to observing "spurious causal factors" (Rawhouser et al., 2019, p. 98).

While some literature treats societal impact as a one-dimensional construct, doing so leads to assessment that is not very informative or actionable (Rawhouser et al., 2019). Many, if not most, authors therefore recognise that there are multiple dimensions that need to be considered separately. Examples of dimensions being used to conceptualise societal impact include (1) the United Nations' 17 Sustainable Development Goals (SDGs) (United Nations Department of Economic and Social Affairs, 2022a), (2) Vanclay's (2003, 2002) distinction between impacts on health and social wellbeing, the quality of the living environment, the economic situation and material wellbeing, culture, family and community, and gender relations, and (3) Bagnoli & Megali's (2011) three-dimensional controlling framework as a performance measurement system for social enterprises. The latter covers three fields of measurement and control: "economic and financial performance", "social effectiveness", and "institutional legitimacy", where Bagnoli & Megali (2011) define key indicators in each area, which can provide a foundation for the necessary designation of context-specific control systems (see Section 3.3).

Beyond the societal impact literature, the triple bottom line is a well-known accounting framework that is built on the idea that the success of businesses, projects, etc. should not only be measured based on their profitability. The measurement should also take into account impact on the environment and society, leading to the "3Ps" ("people", "planet", "profit") as performance dimensions (Elkington, 1994; Hacking and Guthrie, 2008; Slaper and Hall, 2011). This idea of applying these three dimensions to assessing sustainability has become very prominent, also underlying many standards which have been created to have a societal impact (Manning and Reinecke, 2016). While these three dimensions as such are appealing and straightforward, identifying suitable indicators to measure them may often be challenging and it may be difficult to establish measurement methods that allow an overall assessment of performance on all "3Ps" (Scerri and James, 2010; Slaper and Hall, 2011). Relevant indicators therefore need to be determined on a case-by-case basis, depending on the context where the triple bottom line is applied (Hacking and Guthrie, 2008; Slaper and Hall, 2011).

3.2.2 Insights from standardisation literature

Standardisation literature provides three angles for understanding societal impact of standards: First, societal impacts often relate to specific standards. These insights are

[11] They do apply to standardisation committees that develop standards, but these are not our focus.

somewhat limited because we are interested in a more general picture that can be applied across standards. Second, literature classifying standards according to their economic functions takes a more fundamental approach by considering the effects that result from each function. Third, literature also suggests that the standardisation process itself may have substantial societal impact.

Studies on societal impacts of standards

Existing research on the impact of standards has mostly considered economic impacts. Research into the societal impacts of specific standards mainly focusses on the ISO 9000 series of standards for quality management systems, and the ISO 14000 series of standards for environmental management systems. The resulting body of literature remains multifaceted and scattered. Studies show positive impacts, negative or no impacts (Boiral, 2012; Boiral et al., 2018; de Vries et al., 2012). There is no consensus on how to measure these standards' operational or environmental performance. Beyond these empirical studies, Wijen (2014) developed a conceptual model of how different factors in the adoption of sustainability standards affect the extent to which the standard can contribute to organisations becoming more sustainable.

Boiral (2012) and Manders (2015) systematically reviewed empirical studies on the impacts of ISO 9001 to synthesize results about its effectiveness and provide a clear picture of performance indicators, which tend to be heterogeneous. They found that improvements of operational benefits are the most frequently mentioned. This is aligned with the standard's original purpose of improving quality management practices to meet customer needs and enhance effectiveness (Boiral, 2012; Manders, 2015). The exact impact of ISO 9001 varies furthermore depending on the level of economic development and national culture (Manders, 2015). Empirical studies examined the internal and external operational variables and the positive impacts of ISO 9001 on these variables (Boiral, 2012, p. 24).

To measure the impact of ISO 14001 on environmental performance, Boiral & Henri (2012) develop a 'hybrid model' which accounts for both the effects of managerial changes made because of standard implementation, and the changes that firms would have made anyway due to external pressures for environmental-performance improvements. A further systematic review of the adoption and outcomes of ISO 14001 by Boiral et al. (2018) found that the environmental variables to analyse outcomes can be categorized into 'environmental management outcomes', 'environmental indicators', and 'environmental awareness and social aspects'. Other than these main environmental issues, empirical studies also focus on the socio-economic outcomes of ISO 14001 such as improved manufacturing efficiency, cost-saving, customer satisfaction, market position, financial performance, investors' returns and share price, which also were found as impacts of ISO 9001 (Boiral et al., 2018, p. 420).

It is critical to disentangle the impacts of the standard and the impacts of the certification based on the standard (Manders, 2015). Many authors mix up the two and sometimes assume that the impact of getting certified for a management system standard is equivalent to the impact of the standard itself. However, the fact that one of the easiest ways to

demonstrate the implementation of a management system standard and the compliance with the standard is certification should also be considered.

Functions of standards and their effects

Several authors have developed classifications of standards according to the functions that they fulfil (e.g. Blind, 2004; de Vries, 2006, 1998; Egyedi and Ortt, 2017; Kienzle, 1943; Swann, 2010). In these classifications, each standard fulfils one or multiple functions. Possible functions are, e.g., (1) compatibility / interface, (2) minimum quality / safety, (3) variety reduction and (4) information (Blind, 2004), or (1) variety reduction, (2) information, (3) compatibility, (3) measurement, (4) classification, and (5) behaviour protocols (Egyedi and Ortt, 2017).

These classifications are relevant for societal impact measurement insofar that the authors often (theoretically) link certain effects to each type of standard, which in turn may result in impact and can guide the decision on what areas to focus on when measuring it. For example, Blind (2004) names reduction of negative externalities as a positive effect of minimum quality / safety standards, and Egyedi & Ortt (2017) find that variety reduction standards reduce the required human effort in finding a solution to a problem. Table 5 on p.21 provides an overview of the effects that are associated with different functions of standards according to Egyedi & Ortt's (2017) classification.

Some classifications distinguish further between direct changes from implementing a standard (called "inner workings" by Egyedi & Ortt (2017) and "intrinsic functions" by de Vries (2006, 1998)), consequences for the wider system in which the standard is implemented (called "effects" by Egyedi & Ortt (2017) and "extrinsic functions" by de Vries (2006, 1998)). Furthermore, de Vries (1998) argues that some changes and effects initiated by standards may be in the interest of specific stakeholder groups and against the interests of others (he calls these effects "subjective functions"). For example, a standard requiring high quality levels may benefit those who can meet these levels by excluding others from the market. Such nuances can be helpful to develop more targeted approaches to measuring standards' societal impact.

Impacts of the standardisation process

Before standards can be implemented, the standardisation process in which they emerge can already have societal impact. This process is characterised by interaction between stakeholders, which may, e.g., promote innovation in important societal areas, or cause delays in committees' work which obstruct technology-development for societal targets. Such effects are documented, e.g., in the following cases: In e-mobility, committees failed to agree on a common charging plug, sending an image of a divided industry to markets and governments, and substantially delayed the transition towards more sustainable transportation (Wiegmann, 2019b, 2013). In the GSM case, standardisation was essential for strengthening collaboration in the European telecommunications industry, and thus contributed to the vision of a united Europe (e.g. Bekkers, 2001; Pelkmans, 2001). Often, dynamic interactions between committees, governments, and markets has consequences for society (Wiegmann et al., 2017). Recent research shows that potential impact (e.g., driven by

SDOs perceived legitimacy in the market) is a core driver of many companies' strategies for participating in standardisation (Wiegmann et al., 2022a).

Table 5: Standards' functions and their effects (source: Egyedi and Ortt, 2017, p. 119)

Functions of standards	Inner workings	Effects
Primary functions	*Functions that apply to all standards*	
Variety reduction	Defines a selection Identifies relevant characteristics Codifies an order	Reduces 'energy' (human effort, material, physical energy) Acts as a focussing device
Information • Reference	Codifies and formalises negotiated agreements Freezes information Codifies common vocabulary and knowledge building blocks	Provides guidance Eases comparison, increases transparency Eases communication and transactions Creates common infrastructure Eases more complex knowledge creation
Secondary functions	*Functions that only apply to certain standards (i.e., basis for distinguishing standards)*	
Measurement • Reference measure (what) e.g., threshold limit value • Measurement method (how)	Sets the required performance Introduces demarcation Defines a filter (in/out; yes/no) Defines a basis for ranking	Creates a basis for decision making Provides a tool for performance evaluation and compliance testing Creates confidence
Classification	Specifies a normal order (i.e., defines categories)	Allows identification of entities and sorting Allows comparison of category handling/treatment
Behaviour protocol, e.g. instruction, management standard	Codifies the kind and/or sequence of actions	Provides a checklist Supports accountability

3.3 Approaches to societal impact measurement

Many approaches and methods for measuring societal impact have been put forward in fields, such as social entrepreneurship, ethical investments, and development aid. Examples from both academia and practice include applications of the balanced scorecard in sustainability contexts (Hansen and Schaltegger, 2018), the multi-dimensional controlling framework for social enterprises (Bagnoli and Megali, 2011), the performance measurement system (PMS) for social enterprises (Arena et al., 2015), and the standards developed by the Global Reporting Initiative (GRI, 2022a). Several authors have reviewed and evaluated the countless available methods (Hansen and Schaltegger, 2016; Kah and Akenroye, 2020; Maas and Liket, 2011; Ormiston, 2022; Rawhouser et al., 2019). While there is thus no shortage of tools and methods, many of them are criticised for lacking a theoretical underpinning and academic rigour (Rawhouser et al., 2019).

The remainder of this section discusses insights from the literature regarding steps that need to be taken to ensure academic rigour of impact measurement methods and tools. On a fundamental level, Clifford et al. (2014) stress that developing so-called "theories of change" is essential for impact measurement. Building on these theories of change, a number of heuristics are proposed, which can be used to determine the scope of the impact measurement and the indicators.

3.3.1 Theories of change

The "theory of change" approach forms the basis for many impact measurement methods (Clifford et al., 2014; Coryn et al., 2011; Hazenberg and Paterson-Young, 2022; Ormiston, 2022). As originally proposed by Weiss (1997, 1972), context-specific theories of change (also referred to as "logic models") aim to explain the causality behind how impact results from an object of study (which can be an activity, organisation, technology, etc.). Relying on such theories as foundation for impact measurement helps conceptualise what is being measured, and "demonstrates the links between inputs and activities, and the changes that these deliver to individuals, communities and societies" (Hazenberg and Paterson-Young, 2022, p. 17). Furthermore, theories of change allow not only identifying positive and/or negative impacts, but also what causes these impacts and is therefore worth replicating in similar contexts or needs improvement (Coryn et al., 2011).

Table 6: Results Chain (source: Hazenberg and Paterson-Young, 2022, p. 17)

Inputs	What resources are used in the delivery of an intervention?
Activity	What is being done with the 'inputs' (i.e. the intervention)?
Output	How that activity touches on the intended beneficiaries?
Outcome	The change arising in the lives of beneficiaries and others.
Impact	The extents to which that change arises from the intervention.

Many context-specific theories of change are adaptations of two widely used generic models: (1) A logic model that is sometimes referred to as the results chain (Coryn et al., 2011; Ebrahim and Rangan, 2014; Hazenberg and Paterson-Young, 2022; Weiss, 1972), and

(2) a conceptualisation of biophysical and human impacts from the Social Impact Assessment (SIA) literature stream (Slootweg et al., 2001; Vanclay, 2002):

- The central idea behind the first approach is that impact is the result of a chain of concepts which result from each other (see Table 6 on p.22). The further one moves down this chain, the more profound the change caused by an activity becomes, but also the more difficult it becomes to measure and to attribute to the original activity (Ebrahim and Rangan, 2014).
- The latter model (see Figure 2) was developed specifically for societal impact assessment (Slootweg et al., 2001; Vanclay, 2003, 2002). It is more complex because it also takes effects that are triggered indirectly and feedback loops into account, but may consequently offer a more complete picture of the impacts' causality.

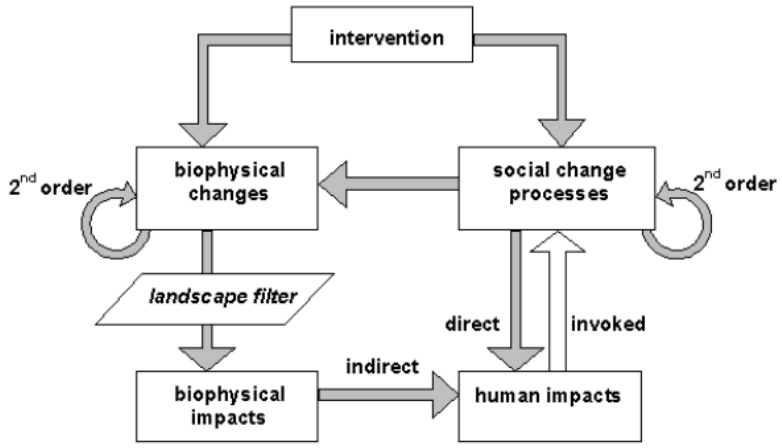

Figure 2: Conceptualisation of biophysical and human impact (source: Slootweg et al., 2001, p. 26)

Although theories of change are widely used as foundations for societal impact assessment, they are not free from critique. Some have criticised the approach for putting too much emphasis on expected outcomes while risking to oversee unanticipated impacts (Arensman et al., 2018; Coryn et al., 2011; Valters, 2014). Furthermore, complex phenomena and contexts may be difficult to capture in a single theory of change, e.g. because theories of change may be too linear or because there may be too many stakeholders involved (Arensman et al., 2018; Barnes et al., 2003; Clifford and Barnes, 2022). Consequently, there is a risk of theories of change being wrongly specified which may result in misleading evaluation outcomes (Coryn et al., 2011). Using mixed-methods and/or qualitative approaches to impact measurement has been suggested as a potential remedy for such limitations (Arensman et al., 2018; Bamberger et al., 2016).

3.3.2 Scope and indicators of societal impact measurement

In addition to establishing a theory of change as the foundation for impact measurement, (1) the scope of the measurement (i.e., which parts of the logic model or Slootweg et al.'s (2001) conceptualisation should be measured) and (2) suitable indicators need to be determined. The first point relates to complexities associated with measuring 'downstream' elements of the results chain (see previous section). This means that it may not always be possible to measure all aspects related to it, although this may also not always be necessary if the link from an outcome to an output or impact is already well-established knowledge

(Ebrahim and Rangan, 2014). The latter point relates to how the measurement can be operationalised.

Literature raises a wide range of considerations that apply in determining these factors, such as the scale and scope of the activities' mission (Ebrahim and Rangan, 2014), the needs of stakeholders (Clifford et al., 2014; Costa and Pesci, 2016), the intended use of the measurement results (categorisation of impact sources or quantification of impacts) (Rawhouser et al., 2019), and whether the measurement method should produce results that are comparable across settings or context-specific (Rawhouser et al., 2019). To address some of the considerations outlined here, literature also offers heuristics, such as Costa & Pesci's (2016) framework for involving stakeholders in designing impact measurement methods and Ebrahim & Rangan's (2014) framework for selecting the right scope along the results chain. Howard-Grenville (2021) furthermore argues that gaining a good understanding of impacts relies on conducting both detailed analyses of processes causing certain impacts, and complementary high-level analyses on broader systems.

Table 7: Example indicators used for different steps of the results chain (source: Ebrahim and Rangan, 2014, p. 121)

Inputs →	**Activities** →	**Outputs** → *Results: immediate*	**Outcomes** → *Results: medium- and long term*	**Impacts** *Results: effects on root causes, sustained significant change*
• Funds • Equipment and supplies • Knowledge and technical expertise	• Basic needs delivery, such as food and shelter • Service delivery, such as job training and counselling • Infrastructure construction, such as transportation	• People fed, housed, or treated • People trained or educated • Roads built and goods transported to market	• Improved quality of life, health, educational attainment, etc. • Increased incomes (measured for individuals)	• Sustained drop in poverty (or obesity, illiteracy, etc.) • Improvements in human development indicators (measured in terms of communities, populations or ecosystems)

Measurement indicators can be designed along three dimensions (financial or non-financial, qualitative or quantitative, forecast or historical) (Clifford et al., 2014). Examples of indicators used in previous societal impact measurement approaches include the ones suggested by Ebrahim & Rangan for different steps along the results chain (see Table 7), but may also include indicators like coherence with the stated mission to measure more abstract concepts like "institutional legitimacy" (Bagnoli and Megali, 2011). Furthermore, a large variety of indicators has been proposed in the context of measuring SDG-performance at different levels (e.g. Sachs et al., 2021; United Nations Department of Economic and Social Affairs, 2022b). In general, indicators are often structured along performance dimensions that may be derived from the theory of change and well-established frameworks of societal-impact dimensions like the SDGs (assuming a multi-dimensional conceptualisation of impact, see Section 3.2), but then need to be adapted for the specific context (Arena et al., 2015; Clifford et al., 2014; Hazenberg and Paterson-Young, 2022).

Altogether, well-designed societal-impact-measurement frameworks should meet the criteria of relevance, helpfulness, simplicity, naturalness, certainty, acceptance,

transparency, and being founded on evidence (Clifford et al., 2014; Clifford and Barnes, 2022).

3.4 Foundation for the next steps: the "Theory-of-Change" approach to standards

Based on the literature reviewed above, we develop our approach to measuring societal impacts of standards. Despite the criticisms highlighted in Section 3.3.1, we selected the Theory of Change / Logic Model as the basis for our work. A *standard-specific logic model* helps understanding and showing what changes result from implementing a standard and the causality behind impact. It can also guide empirical measurement by specifying what to measure and pointing towards appropriate indicators. Using the results chain (see Table 6 on p.22), a specific logic model can be developed for each case.

Below, we outline how the results chain can be applied to the standards context. Section 3.4.1 explains the underlying logic of our approach. Section 3.4.2 then explains how the results chain is applied to the standards context. Finally, Section 3.4.3 discusses how the impacts can be linked to SDGs in our approach. All analyses in Chapters 6 and 7, as well as the impact measurement methodology described in Chapter 8 build on this reasoning.

3.4.1 Background information: the logic behind the "Theory-of-Change" approach to standards

As a point of departure, we refer to de Vries's (1997) definition of standards. According to this definition, standards solve matching problems, which result from interrelated entities not harmonizing with each other (de Vries, 1997). To solve these problems, features of these entities must be adjusted "in a way that they harmonize with each other" (de Vries, 1997, p. 79). Entities include, e.g., products, materials, software, services, processes, and/or management systems. Impact relies on actual implementation of the standard: Change occurs only if existing entities are actually changed or new entities are created according to the standard.

A standard's impacts thus result from how it (re)shapes such entities. The standard prescribes which characteristics these entities should have after implementing the standard (e.g., a management system meeting certain requirements, or an interface following certain technical specifications). Developing a theory of change for a standard applies a process view on how entities are (re)shaped, and what consequences this has. This view takes a close look at:

1. the necessary steps to reach the prescribed shapes of entities (i.e., standard implementation), and
2. the consequences of shaping entities in this manner, which translate into impact.

This process is captured in a five-stage logic model for standards (see Figure 3 on p.26). Section 3.4.2 explains how this model is applied.

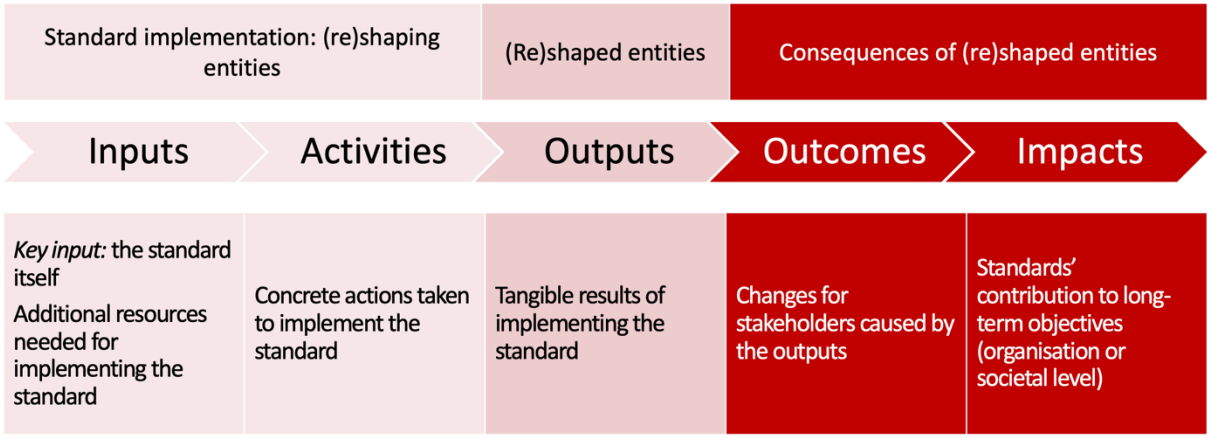

Figure 3: Logic model applied to standards (source: drawn by authors, based on Clifford et al., 2014, p. 29)

3.4.2 Logic model for standards

Figure 3 provides an overview of how the results chain can be used to develop a logic model. The model takes a process perspective on how standards achieve impact. Impacts are achieved via inputs, activities, outputs, and outcomes. Concrete examples of what these steps entail can be found in the summaries of our in-depth case studies in Chapter 6.

Inputs

Inputs are what is invested and used in activities necessary to bring outputs, generate outcomes, and create impact (Hehenberger et al., 2015). Inputs may be financial, intellectual, human, premises, or others (Clifford et al., 2014), sometimes summarised as 4M: material; method; machine; man.

In the standards context, the *key input is the standard itself*. Furthermore, additional resources are needed for implementing a standard (e.g., money, time, expertise, consultancy, equipment, facilities, information, materials).

Activities

Activities are the concrete actions taken, using identified inputs, to deliver the intended outcome to the intended beneficiaries (Hehenberger et al., 2015). In the standards context, activities are *what must be done to (re)shape entities so that they fulfil the requirements of the standard* (i.e., standard implementation). They cover (1) activities to implement the standard; and (2) activities to maintain the implementation.[12] An example for the latter, may be the recurring training of employees needed to meet a standards' internal auditing requirement.

Outputs

Outputs are the results of activities and show how the intended beneficiaries were reached. In the standards context, outputs are *the tangible results of implementing the standard*. In line with de Vries's (1997) definition cited in Section 3.4.1, the results are (re)shaped entities, which meet the requirements of the standard and solve a matching problem.

[12] Recurring activities prescribed in the standard itself are not included. For example: If a standard requires setting up a new process, then only activities needed to implement the process (designing the process, consulting involved staff, etc.) are covered, but not carrying out the process itself on a continuing basis.

Adapted entities may, e.g., be products, materials, services, software, processes, systems, and/or reports,[13] and may be newly created or modified. Multiple outputs may result from implementing one standard.

Outcomes

Outcomes are short- or long-term changes achieved through the outputs for the beneficiaries (Clifford et al., 2014). In the standards context, outcomes are *changes for stakeholders*[14] *that are caused by the outputs*. Outcomes may occur at the level of the organisation implementing the standard, or accumulate at an aggregate level (e.g., industry sector, country). They can be attributed to specific stakeholders and are categorised into: (1) positive, negative and/or neutral depending on their societal effects; and (2) intended or unintended.[15]

For many standards, certification is an outcome from implementing the standard. In cases where certification is relevant, the analysis should disentangle the implemented standard's effects from certificates' signalling effects (a certificate signals that something meets the requirements laid down in the standard). Certification is an outcome that becomes possible due to products, systems, etc. (outputs) meeting the standard's requirements.

Impacts

Following OECD (2021, p. 28), we define impact as "the difference in a specific outcome compared to a counterfactual, or estimate what would have happened without the programme [in our case: standard]." While outcomes are the direct changes resulting from a standard, *impacts are what standards contribute to (or detract from) long-term objectives*. Such long-term objectives may relate to the organisation, or the society as a whole. Impacts can accumulate at the aggregate level.

Assessing impacts therefore requires estimating what would have been achieved without the standard, compared to what has been achieved with the standard. This implies that effects of standards other than the one being evaluated should be considered to delineate the focal standard's impacts. Ideally, impacts are assessed by comparing (1) *organisations that implement the standard with organisations that do not* (i.e., no or other standards applied), or (2) the *situation before and after standard implementation*.

3.4.3 Linking impacts to the SDGs

The literature reviewed in Section 3.3 (e.g. Clifford et al., 2014) shows that logic models derived in the manner outlined above are very context specific and not generalisable. This means that applying the approach outlined above is likely to reveal impacts that are standard-specific, and not easily comparable across standards.[16] In order to ensure that standards can be compared in terms of their societal impacts, we selected the United Nations Sustainable Development Goals (SDGs) (United Nations Department of Economic

[13] Many outputs, such as systems or products, may be broken down further into the components that make them up. We consider the output in its simplest form as the "key output".

[14] In line with the literature reviewed above, we assume that environmental impacts also affect stakeholders. A broader view may consider the environment as a category on its own.

[15] Unintended outcomes may be negative or positive. They may be unforeseen and include outcomes which reach stakeholders other than the intended ones (see Hehenberger et al., 2015).

[16] The experiences from our in-depth case studies (see Chapters 6 and 7) confirm this expectation.

and Social Affairs, 2022a) as a framework for classifying identified impacts. After deriving a standard's logic model, the identified impacts can thus be categorised in terms of the SDG(s) that they relate to in order to enable comparison across standards.

4 Studies about ISO 9001's and ISO 14001's impacts: literature review

As pointed out in Section 3.2.2, limited research is available on societal impacts of standards. Notable exceptions are the ISO 9000 (quality management systems) and ISO 14000 (environmental management systems) series, which have attracted substantial interest in the academic community. This chapter summarises the results of two 'rapid reviews' (see Dobbins, 2017; Khangura et al., 2012) of studies on the impacts of the core standards in these series: ISO 9001 (Section 4.1) and ISO 14001 (Section 4.2).

Both reviews cover academic literature in the 'Web of Science' and 'Scopus' databases (see an outline of the methods in Appendix 11.5). Research assistants Meihui Jiang and Janne Hesen assisted us in identifying relevant literature and summarising the information in it.

4.1 Impacts of ISO 9001 (quality management systems)

Our screening procedure resulted in 139 studies, which were published between 2001 and 2022,[17] being included in the review of ISO 9001's impacts (see Figure 4, a complete list of studies is available from the authors on request). In Section 4.1.1, we summarise the most important insights. Section 4.1.2 briefly discusses what these insights show about ISO 9001's impacts on the United Nations' SDGs.

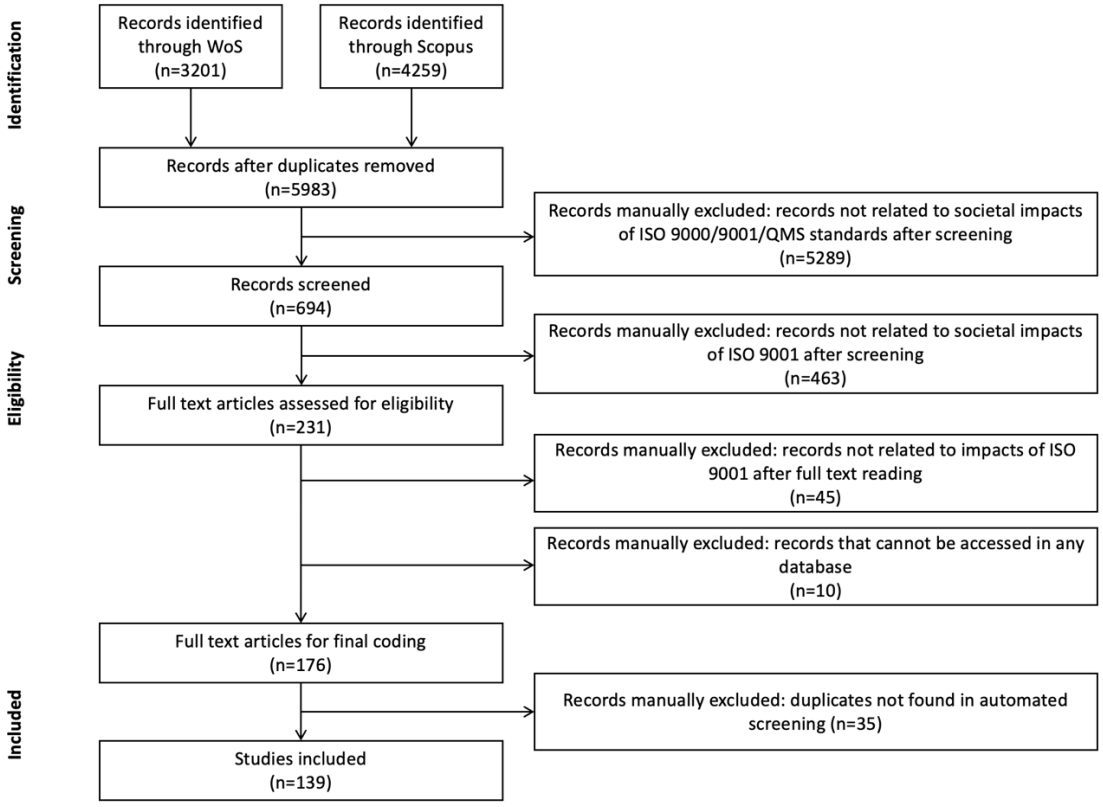

Figure 4: PRISMA Diagram of studies on ISO 9001's impacts

[17] Although we looked for studies ranging back to 1987 (when ISO 9001 was first published), no studies published before 2001 passed the screening process (see Appendix 11.5).

4.1.1 Overview over insights from literature

The studies report evidence, either at the organisational level or the macro-level, from individual countries (42 different countries, covering both developed and developing nations) or compare evidence across multiple countries. They also cover a large variety of industry sectors. Most studies report quantitative evidence (100 studies) of impacts.

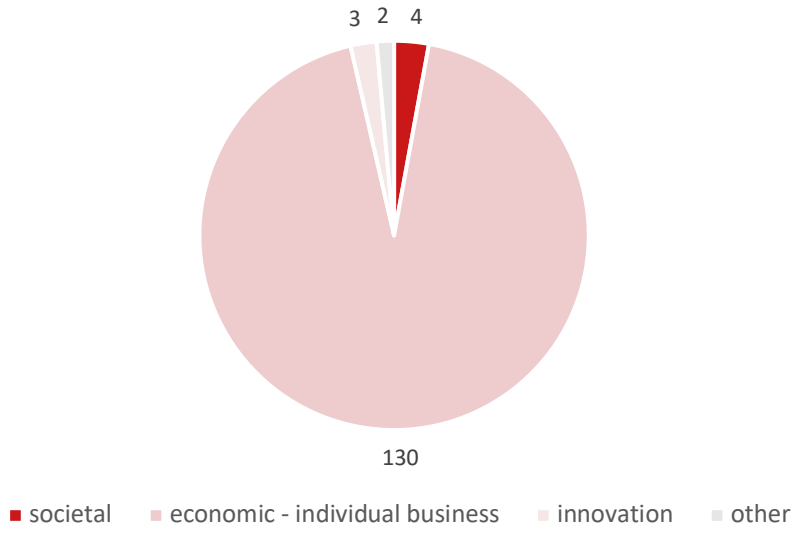

Figure 5: Impact categories identified in literature about ISO 9001

The vast majority of studies in the sample (130 papers) address economic impacts on businesses (see Figure 5). Only four papers (Albulescu et al., 2016; Chiarini, 2016; Lim and Prakash, 2017; Sin et al., 2021) focus on non-economic societal impacts. We distinguished further between (1) studies investigating direct impacts of implementing ISO 9001, and (2) studies of ISO 9001 certification's impacts.

A small share of the literature (39 papers) investigates impacts of implementing ISO 9001. Examples are improved organisational efficiencies in public sector organisations (To et al., 2011), enhanced operations in hospitals (Ritchie et al., 2019), and supporting companies in participating in public tenders in construction projects (Ng et al., 2012)

Most papers focus on impacts of ISO 9001 certification. This includes the four studies of non-economic societal impact (Albulescu et al., 2016; Chiarini, 2016; Lim and Prakash, 2017; Sin et al., 2021), which have been address both at the macro- and the organisational levels. Lim and Prakash (2017) focussed on the macro-level. They found that countries with larger numbers of ISO 9001-certified businesses have lower workplace-accident rates. They explain this as being due to the need to establish well-designed internal processes when implementing ISO 9001, which contribute to safer working-environments. Also at the macro level, Albulescu et al. (2016) found no effect of ISO-9001 certification on labour productivity within the EU-27 countries. At the organisational level, Sin et al. (2021) investigated employees in the Malaysian hospitality sector: Employees of ISO-9001 certified companies are more sustainability-conscious than their peers at non-certified organisations. Chiarini (2016) studied Italian local-government organisations: Those with ISO 9001 certification have higher staff-awareness of citizen's needs and higher citizen-satisfaction. However, ISO-

9001 certified local governments score lower on citizen participation and are perceived as more bureaucratic.

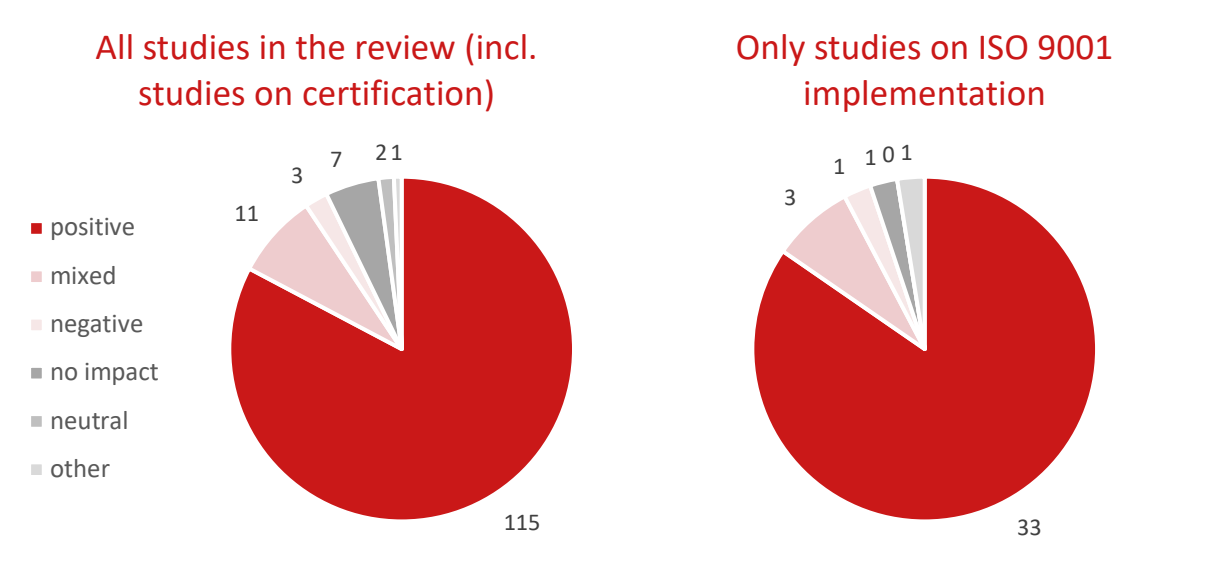

Figure 6: Nature of impact identified in literature about ISO 9001

As the examples above show, impacts identified in the reviewed studies range from positive to negative, with some studies (e.g. Chiarini, 2016) showing mixed results. Nevertheless, Figure 6 shows that the vast majority of identified effects are positive. This applies both to all studies in our review combined (left graph in Figure 6), as well as to the research that investigates specifically focusses on the effects of implementing ISO 9001 (i.e., not on the effects of certification, right graph in Figure 6).

4.1.2 Discussion: relating the results from literature to the SDGs

These findings can also be related to the United Nations' SDGs. The majority of studies which address the economic effects on individual businesses suggest that ISO 9001 and/or ISO 9001 certification contribute to the 'economic-growth aspect' of *SDG 8 ("Decent Work and Economic Growth")* and *SDG 9 ("Industry, Innovation and Infrastructure")*.

Studies related to other SDGs are scarce, meaning that one should be reluctant in drawing conclusions. Without replication of these results in other contexts, it is unclear to what extent the findings are valid across countries and organisations. Bearing this in mind, the reviewed literature suggests that ISO 9001 (certification) also contributes to a number of other SDGs:

- Improved workplace-safety (Lim and Prakash, 2017) relates to the 'decent-work aspect' of *SDG 8* and *SDG 3 ("Good Health and Well-Being")*. However, the finding that ISO 9001 does not improve labour productivity (Albulescu et al., 2016) suggests that impact on these SDGs may be limited.
- Increased sustainability-consciousness of employees (Sin et al., 2021) contributes to *SDG 12 ("Responsible Consumption and Production")*.
- The mixed effects observed in Italian public administration (Chiarini, 2016) are directly related to the 'strong-institutions aspect' of *SDG 16 ("Peace, Justice and Strong Institutions")*.

ISO 9001 was developed for business contexts. It specifies requirements for quality management systems of producing companies, aiming to increase customer satisfaction. However, the last example shows that the standard is also used in non-commercial organisations such as public services. Some public services are also addressed by specific variants of ISO 9001, although they were not covered by our literature review.[18] This broadens its potential scope to SDGs related to these organisations. Beyond SDG 16, ISO 9001 or its variants may, for example, affect SDG 3 (*"Good Health and Well-Being"*), SDG 4 *("Quality Education")*, and SDG 17 *(Partnerships for the Goals).* Further research on ISO 9001's societal impacts may also consider such effects on other SDGs.

4.2 Impacts of ISO 14001 (environmental management systems)

Our screening procedure resulted in 168 studies, which were published between 2000 and 2022,[19] being included in the review of ISO 14001's impacts (see Figure 7, a complete list of studies is available from the authors on request). In Section 4.2.1, we summarise the most important insights. Section 4.2.2 relates these findings to the United Nations' SDGs.

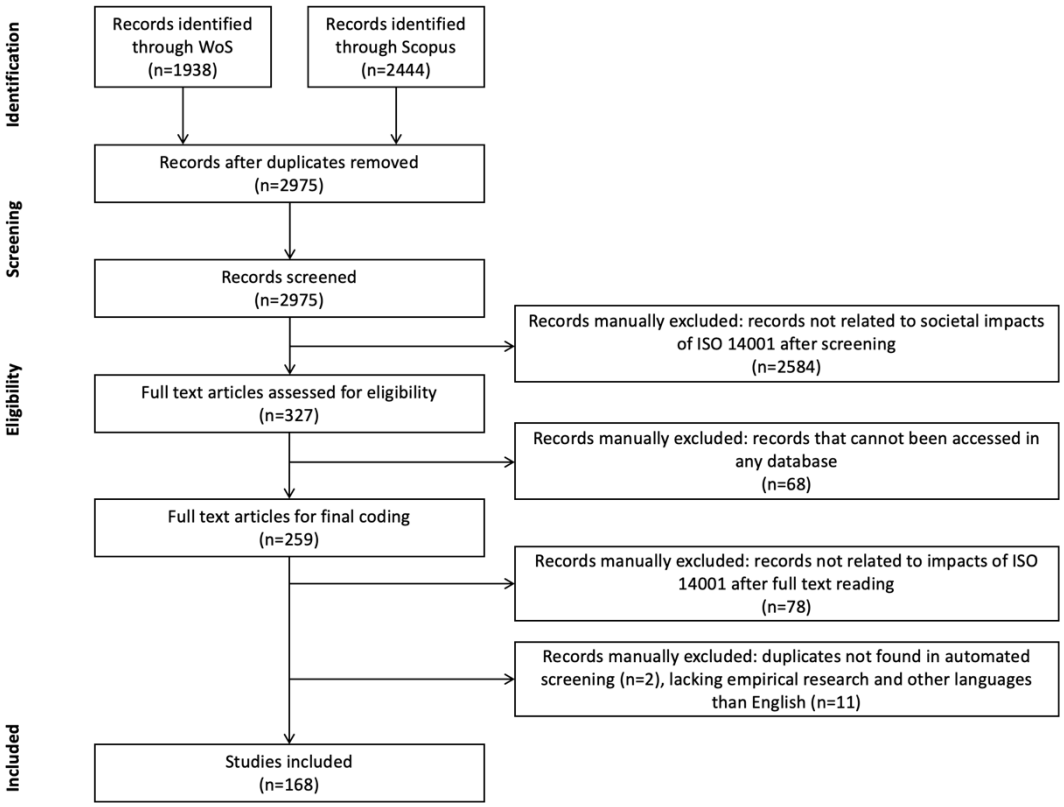

Figure 7: PRISMA Diagram of studies on ISO 14001's impact

4.2.1 Overview over insights from literature

The studies report evidence at the organisational level (122 studies), the country level (47 different countries, covering both developed and developing nations), or across multiple

[18] Examples include EN 15244 (*"Quality management systems – EN ISO 9001:2015 for healthcare"*), ISO 21001 (*"Educational organisations - Management systems for educational organizations - Requirements with guidance for use"*), and ISO 17021 (*"Requirements for Certification Bodies"*).

[19] Although we looked for studies ranging back to 1996 (when ISO 14001 was first published), no studies published before 2002 passed the screening process (see Appendix 11.5).

countries (e.g., South Asian Association for Regional Cooperation countries, SAARC; EU). They also cover a large variety of industry sectors (e.g., construction, manufacturing, automotive, energy, or multiple sectors). Most studies report quantitative evidence of impacts (125 studies), as in the literature reviewed about ISO 9001's impacts.

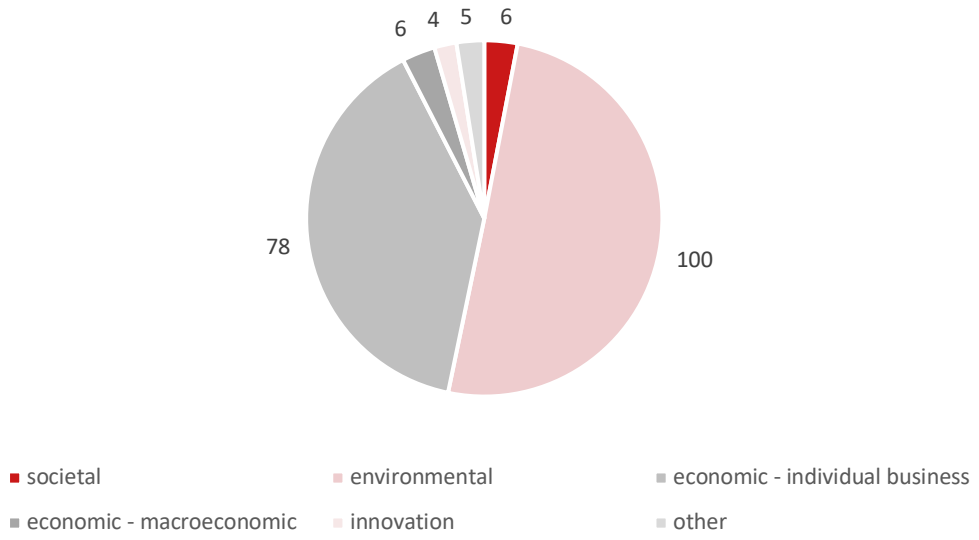

Figure 8: Impact categories identified in literature about ISO 14001

Most studies in our sample address environmental impacts and/or economic impacts on businesses (see Figure 8). 21 papers address both. Implementing ISO 14001 and/or obtaining ISO 14001 certification contributes to improving organisations' operational and/or environmental performance. Environmental Management Systems (EMS), which are certified based on ISO 14001, have significant impact on corporate performance. furthermore, environmental performance improves over time, as experience with such systems accrues (Melnyk et al., 2003). A review of multiple studies revealed that the standard impacts positively on environmental management (e.g., regulatory compliance and green supply chain) and environmental performance (e.g., air pollution, waste management, energy and resource consumption) (Boiral et al., 2018).[20]

Figure 9 on p.34 shows that most impacts in the reviewed papers are positive (101 papers), although this may to some extent be related to biases in the underlying data (Boiral et al., 2018; de Vries et al., 2012). 46 papers identify mixed results. For example, ISO 14001's impact on firms' value added depends on export orientation (Nishitani, 2011). Curkovic and Sroufe (2011) find that ISO 14001 certification may contribute to more sustainable supply chains. The standard supports facilities in reducing negative impact on some dimensions (i.e., natural resource use, solid waste generation) but is less effective on others (i.e., wastewater effluent) (Arimura et al., 2008). ISO 14001 also supports certified firms' operational performance, but this effect diminishes in the long-run (Treacy et al., 2019). Positive impacts may depend on factors specific to countries, industries, and firms.

[20] Boiral et al. (2018) emphasise that literature findings are based on managers' perceptions, which may be influenced by social desirability bias or self-reporting bias.

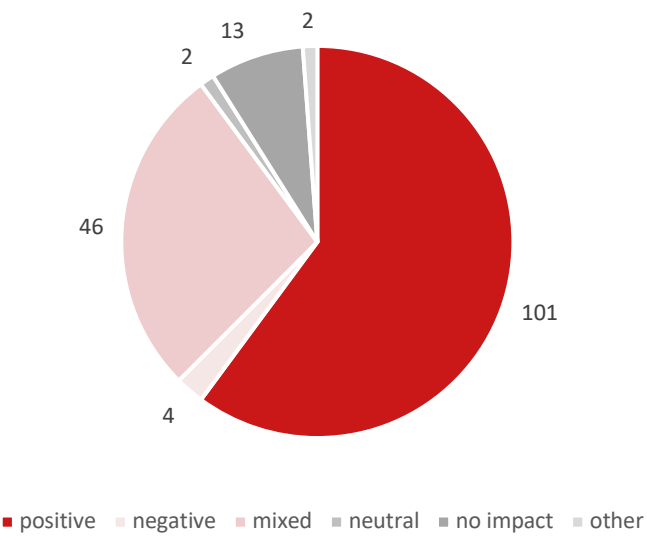

Figure 9: Nature of impact identified in literature about ISO 14001

Motivations for implementing the standard affect environmental performance. Internal motivation has a positive effect on internalising ISO 14001, which consequently improves a firm's environmental performance (Qi et al., 2012). Only relative improvements in environmental practices and performance were found where implementing ISO 14001 was driven by external pressures (i.e., concern for institutional legitimacy) (Boiral, 2007).

Most papers investigate effects of implementing ISO 14001 in combination with certification (127 papers). Many studies examine effects of implementing EMS by investigating the adoption of the standard, or use certification as a proxy for standard implementation. Boiral et al. (2018) find that many studies in their review focus on what makes certified systems effective. Studies that also analyse drawbacks of the standard "found significant obstacles and pitfalls related to the lack of internal commitment and the administrative burden of the standard. From this perspective, the main question is not whether or not the standard is effective, but rather what criteria are taken into account to measure its impacts and what are the conditions for its successful adoption. The literature has identified several success factors and contextual aspects, such as the internalization of the standard, its early adoption and its maturity inside the organization" (Boiral et al., 2018, p. 424).

Only six papers address non-environmental societal impacts (see Figure 8). They find a number of effects: Related to employees, ISO 14001 improves awareness of environmental issues (Boiral et al., 2018; Ociepa-Kubicka et al., 2021; Vnoučková et al., 2015), facilitates health and safety at work (Chiarini, 2017; Massoud et al., 2012; Vnoučková et al., 2015), and supports employee-growth and skills (Chiarini, 2017). The standard also benefits ties with external stakeholders: It improves companies' attractiveness for customers (Chiarini, 2017; Ociepa-Kubicka et al., 2021), their relationships with local communities (Boiral et al., 2018; Chiarini, 2017; Ociepa-Kubicka et al., 2021; Vnoučková et al., 2015) and their general reputation (Boiral et al., 2018). Horry et al. (2022) directly link ISO 14001 to the United Nations' SDGs, based on a study in the architectural, engineering and construction (AEC)

sectors. They found that the standard can help achieve SDGs 4 (*"Quality Education"*)[21], 8 (*"Decent Work and Economic Growth"*), 12 (*"Responsible Consumption and Production"*), and 13 (*"Climate Action"*).

Furthermore, some studies address ISO 14001's impacts on innovation (Gazoulit and Oubal, 2021; Iosifov and Ratner, 2018; Radonjič and Tominc, 2006). The underlying idea is that ISO 14001 encourages organisations to innovate to diminish negative environmental impacts. Studies categorised as having other impacts demonstrate that ISO 14001 contributes to sustainable supply chain management (Curkovic and Sroufe, 2011; Zimon et al., 2020).

4.2.2 Discussion: relating the results from literature to the SDGs

The findings from our literature review can be related to the United Nations' SDGs. The majority of studies which address the economic effects on individual businesses suggest that ISO 14001 contributes to the 'economic-growth aspect' of *SDG 8 ("Decent Work and Economic Growth")* and *SDG 9 ("Industry, Innovation and Infrastructure")*.

Studies which address ISO 14001's effects on environmental performance suggest that it contributes to SDGs concerning the environment. Improving organisations' environmental performance impacts on *SDG 11 ("Sustainable Cities and Communities")* and *SDG 12 ("Responsible Consumption and Production")*. Many studies suggest that the standard succeeds in promoting environmental performance or reducing negative effects on the environment. The standard therefore contributes to *SDG 6 ("Clean Water and Sanitation")*, *SDG 7 ("Affordable and Clean Energy")*, *SDG 13 ("Climate Action")*, *SDG 14 ("Life Below Water")* and/or *SDG 15 ("Life on Land")*.

Studies related to other SDGs are scarce, meaning that one should be reluctant in drawing conclusions. Without replication of these results in other contexts, it is unclear to what extent the findings are valid across countries and organisations. Bearing this in mind, the reviewed literature suggests that ISO 14001 also contributes to two other SDGs:

- Improved workplace health and safety (Chiarini, 2017; Massoud et al., 2012; Vnoučková et al., 2015) relates to the 'decent-work aspect' of *SDG 8 ("Decent Work and Economic Growth")* and *SDG 3 ("Good Health and Well-Being")*.
- By supporting regulatory compliance (Horry et al., 2022), the standard contributes to the 'governance' and 'strong-institutions' aspects of *SDG 16 ("Peace, Justice and Strong Institutions")*.

[21] This counter-intuitive finding is supported by effects of ISO 14001 relating to, e.g., improved public awareness of environmental issues, and improved training of employees.

5 Pre-study: dimensions of standards' potential impacts

This chapter reports a pre-study about potential societal impacts of 48 selected standards, which was completed under the guidance of Prof. Dr. Ir. Henk J. de Vries by 48 Bachelor students participating in the minor "Responsible Innovation" in September/October 2021, and master student Koen Snieder. The selected standards cover a broad range of technical fields. Potential societal impacts are indicated qualitatively, and classified in terms of the United Nations Sustainable Development Goals (SDGs), and an additional category "Consumer Protection".[22] See Chapter 2.2.1 for an outline of how we selected standards for this pre-study, and the procedures followed for the analysis.

5.1 Types of impact: classification of the findings

We distinguish between different types of impact: Based on these identified impacts, we estimated whether a standard's overall impacts per SDG would be positive, negative, or mixed. Furthermore, we distinguish between primary and secondary impacts.

Positive, negative and mixed impacts

Each standard is categorised based on its effect on each relevant SDG (positive, negative, mixed). The effects are mixed if a standard both helps and harms the objectives of an SDG. This may happen if a standard helps one stakeholder of an SDG while (in)directly hurting another.[23]

Since this study only aims to explore the diversity and range of societal impact, only one impact is identified per SDG unless there is also an impact that leads to the SDG being labelled as mixed. In that case, both a positive and a negative impact is reported.

Primary and secondary impacts

As outlined in Section 2.2.1, a three-step process was followed in identifying impacts. Based on this process, we distinguish between primary and secondary impacts:

1. *Primary impacts* relate to the core of the standard. This means that the standard was established with this specific objective in mind.[24] The term "primary" suggests only a

[22] We did so because consumers are not covered by the SDGs but are relevant for many standards, as illustrated by the findings shown in Section 5.2.

[23] For example, EN 13031-1 (Greenhouses - Design and construction - Part 1: Commercial production greenhouses) positively contributes to SDG 15 (*life on land*), because it makes greenhouses easier to adopt. Greenhouses may potentially replace farmland, which may reduce the space needed to achieve a given crop yield. The freed-up space can be returned to nature, positively affecting most wildlife. However, nocturnal wildlife can get disturbed due to greenhouses' light pollution. The standard therefore has mixed potential impact on SDG 15.

[24] For example, ISO/IEC 27701 is scoped as follows: "This document specifies requirements and provides guidance for establishing, implementing, maintaining and continually improving a Privacy Information Management System (PIMS) (…) for privacy management within the context of the organization." The primary impact is therefore enhanced privacy.

single impact, but some standards have multiple primary impacts if the primary purpose significantly influences several societal dimensions.[25]

2. *Secondary impacts* do not stem from a standard's stated objective, but can be derived from information provided elsewhere in the standard.[26]

5.2 Findings: potential impacts of the standards included in the pre-study

Table 8 on p.37 provides an overview of the potential impacts per SDG for each of the 48 standards included in the pre-study. Sections 5.2.1 to 5.2.3 provide three examples to illustrate the scores in Table 8.

Table 8 should be read as follows: Colours in indicate whether the impact is positive (green), negative (red), or mixed (yellow). The letter P and a dark colour indicate primary impacts, an S and a light colour indicate secondary impacts. If there is a positive primary impact and negative secondary impact, this is indicated with a brown colour.

Table 8: Overview of potential societal impacts of standards in the pre-study

Standard	SDGs+																	Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	C.P.	
NEN 8112								P										S	2
IEC 62443-2-1						P	P		P	S						S		S	6
ISO/IEC Guide 46									S			P	S					P	4
EN-IEC 61439-1							P	P	S						S				4
EN-ISO 80079-36								P							S			S	3
EN-IEC 61000-4-2								P	S	S		P						P	5
ISO 3184								P	S										2
EN-IEC 60086-3										S		P			S			S	4
EN-ISO 14971			P					P											2
EN-ISO 8559-1					S			P	S	S		S							5
NPR 9998			P						S		P		S						4
ISO 31000								P	S			S	S						4
ISO 21384-3		S	S					P	S				S		S	S			7
EN-IEC 62446-1							P				S	S	P						4
EN-ISO 14644-1			S						P										2
EN 13445-1								P	P										2

[25] For example, IEC 62443-2-1 focuses on ensuring stability and security of industrial automation and control systems. Its primary impacts, apart from purely economic gain, are therefore related to critical infrastructures such as assuring a stable and clean water supply (SDG 6), access to energy (SDG 7), and protecting industry and other infrastructure (SDG 9). Each of these impacts is labelled as "primary" since they directly follow from the standard's objective as stated in its scope.

[26] For example, ISO 8559-1 *Size designation of clothes — Part 1: Anthropometric definitions for body measurement* prescribes how the clothing industry should measure the human body. The primary impact relates to SDG 8, decent work, and economic growth. Secondary impacts are found from a list of all the imaginable body measurements that is part of the standard. The measurement methods also capture body types deviating from the "norm". This relates to SDG 10 (*reduced inequalities*).

Standard	SDGs+																	Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	C.P.	
NEN 1414-1								P										P	2
EN 50128								P	S		S							P	4
ISO 45001								P											1
EN 206 + NEN 8005						S		S	S		S	P							5
EN-ISO/IEC 27701									S							S		P	3
NEN 5077			S						S	S	P								4
NEN 2767-1								S	S		S							P	4
EN 13031-1		P				S			S				S		S				5
NTA 8800							P		S		S								3
ISO 26262-2									P			S						P	3
EN-IEC 60825-1								P	S			S			S			P	5
NEN 1010							S	P	S		P							P	5
EN-ISO/IEC 27002								S	P							S		P	4
EN 15224			P	S						S								S	4
NPR 3378-1								P			S	S	S					P	5
NEN 9997-1									P		P							S	3
NEN 1006						P						S							2
EN-IEC 60204-1								P			S								2
EN-ISO 13485			P						S										2
EN-ISO 15614-8									P										1
EN-IEC 62305-4			S					P			S	S						S	5
NEN 5707						S		P										P	3
EN-ISO 12944-1								S				P		S	S			S	5
CEN/TS 16937								S	P	S		P		S	S			S	7
ISO/TS 15311-1				S					P	S									3
EN-ISO 50001							P		S			S	S						4
EN-ISO 22000		S						S				P					S	P	5
EN-IEC 60601-1			P					P				S							3
NEN 3650-1						S		S	P			S			S			S	6
NEN 5740		S				S								S	P				4
ISO/IEC Guide 98-1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	18
EN-ISO/IEC 17025		S	S			S			P			P	S	S	S				8
																			Total: 198

5.2.1 IEC 60601-1 Medical electrical equipment – Part 1: General requirements for basic safety and essential performance

This standard supports producers of medical electrical equipment in assuring a basic level of safety for medical staff and patients while keeping the medical device's essential performance. The standards potential impacts relate to three SDGs:

1. *SDG 3 (good health and well-being); positive primary impact*: The standard aims to improve healthcare.
2. *SDG 8 (decent work and economic growth); positive primary impact*: The standard aims to assure safe and secure working conditions for medical staff (e.g., in hospitals).
3. *SDG 12 (responsible production and consumption); mixed secondary impact:* Although the standard was not created with the intent to affect the environment, some aspects of the standard impact it positively, whereas others have negative impact:
    a. The standard prescribes addressing environmental risks associated with the disposal of the equipment at the end of its lifetime in the product documentation. This may reduce incorrect disposal of medical equipment.
    b. The standard's focus on safety may harm the environment: The standard requires manufacturers to communicate the expected service life as a fixed period. Instead, a variable expected service life based on the quality of maintenance could extend the period the medical device can be used, leading to less waste.

5.2.2 ISO/IEC Guide 98-1 Uncertainty of measurement — Part 1: Introduction to the expression of uncertainty in measurement

Measurement helps decision processes in activities as diverse as, for example, healthcare, industrial processes, scientific research, and environmental management. Awareness of measurement uncertainty enables – among others – making comparisons, estimating the probability of incorrect decision-making based on measurement, and managing the consequential risks. This guide helps preparing a framework for determining and communicating uncertainties in measurements. This may lead to better understanding of and communication about uncertainties in measurements. Measurement is essential for each SDG to assess both current performance and improvements in a "plan – do – check – act" approach. Therefore, this standard has primary impacts on all SDGs.

5.2.3 CEN/TS 16937 Nanotechnologies – Guidance for the responsible development of nanotechnologies

This standard provides guidance on responsible development of nanotechnologies. Implementing it has consequences for how industry produces products in which nanotechnologies are applied. Its potential impact relates to five SDGs as well as consumer protection:

1. *SDG 9 (Innovation, industry and infrastructure); positive primary impact, negative secondary impact:* If the standard indeed contributes to responsible development of nanotechnologies, this contributes to SDG9. However, there is a danger that companies suggest more responsibility than justified, leading to a potential secondary negative impact for the same SDG.
2. *SDG 8 (decent work and economic growth), SDG 14 (life below water), SDG 15 (life on land), consumer protection; positive secondary impact:* The standard requires (1) identifying the nanotechnology activity, (2) a risk/benefit analysis that considers exposure to the public, to the environment and to workers, and (3) weighing the benefits and the risks while considering the assessment's estimated reliability. Best

practices should be shared within the industry. This may mitigate safety risks for consumers, reduce environmental harms, and protect workers.

3. *SDG 12 (sustainable consumption and production); positive secondary impact:* The standard prescribes developing protocols for stakeholder involvement in decision-making about nanotechnologies' design and production, and acknowledging social and ethical implications.
4. *SDG 10 (reduced inequalities); positive secondary impact:* Sophisticated technology may benefit privileged people more than people in less privileged positions and this standard requires manufacturers to addresses this issue.

5.3 Findings: cumulative potential impacts of the standards in the pre-study

Figure 10 depicts the impact mix across the 48 standards covered by the pre-study: many more positive potential impacts (182) than mixed potential impacts (15).[27] Only one observed potential impact is purely negative. For most of the societal dimensions where we identified a potential negative impact, we therefore also found a potential positive impact.

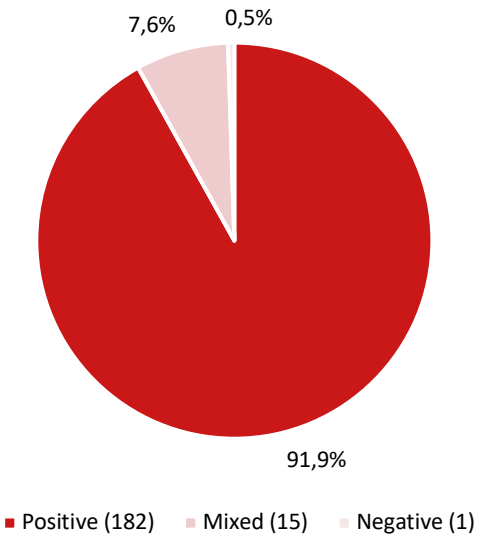

Figure 10: Impact mix of standards in the pre-study

Figure 11 on p.41 shows how often the 17 SDGs and "*Consumer Protection*" were expected to be impacted by the 48 standards in the pre-study. The highest scores are for SDG 9 (*build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation*), SDG 8 (*promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*), and *consumer protection*. A possible explanation is that standards are predominantly used in business and industry contexts. Furthermore, consumer safety is a frequent topic in standards.

[27] Based on counting the findings recorded in Table 8.

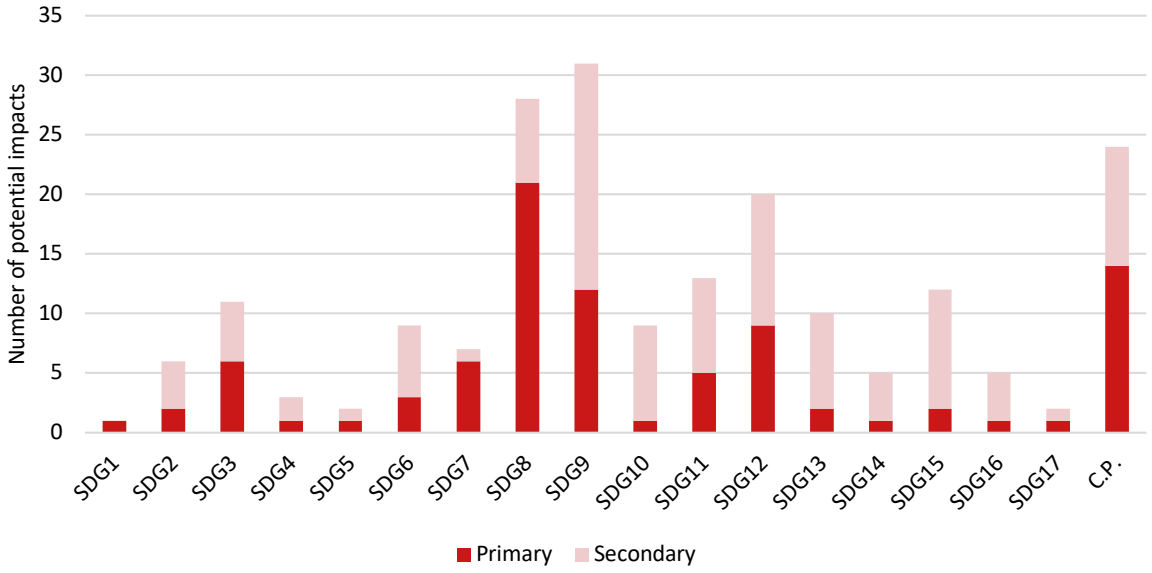

Figure 11: Count of potential societal impacts in the pre-study

Figure 12 shows how many SDGs and *"Consumer Protection"* are potentially affected by standards in the pre-study. For example, the figure shows that two standards affect only one SDG (leftmost bar), whereas nine standards have potential impacts on two SDGs (second bar from the left). The median number of societal impacts per standard is four, and the mean number of SDGs potentially affected by the 48 standards in our pre-study is 4.125.

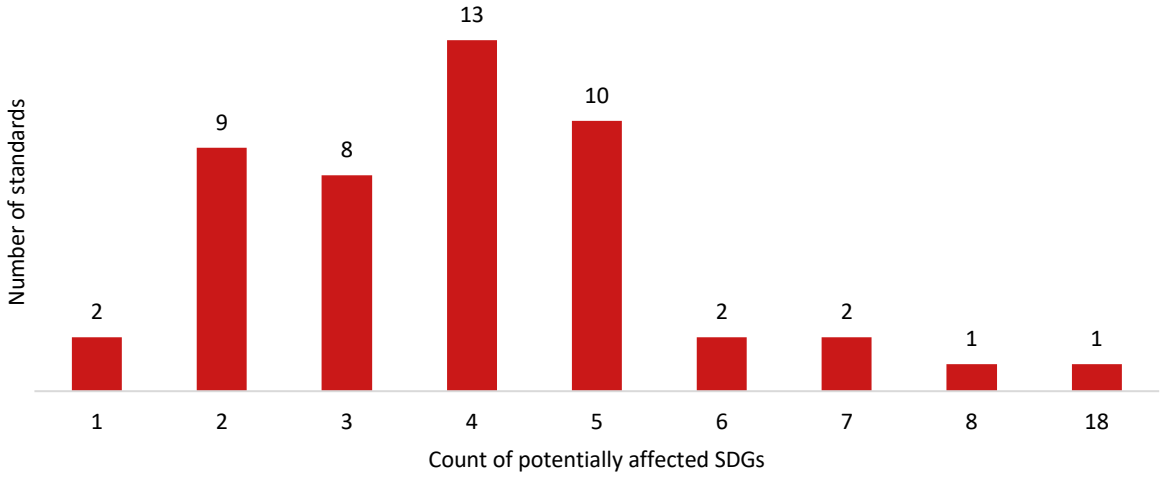

Figure 12: Frequency bar chart of the number of SDGs potentially affected per standard

5.4 Pre-study: discussion and conclusions

Our study shows very positive findings. Of course, standards can be developed with various intended purposes in mind and finding societal impacts is not a surprise. However, most of the 48 standards in the pre-study had been developed 'just' for business reasons. This makes it remarkable that we found so many societal dimensions, and that most of the expected impacts are positive.

A first explanation for these positive potential impacts is that standards are made to improve the current situation. Besides improving economic performance, standards are

often given additional features that improve societal dimensions. This suggests that the stakeholders who develop standards are aware of such dimensions. A second explanation is that the pre-study mostly relied on the standard documents themselves. Negative impacts may not become obvious without consulting further evidence. Our in-depth case studies, which are based on empirical data, are more comprehensive in this regard (Chapters 6 and 7). This pre-study of 48 standards is limited to *potential* impacts, without empirical evidence.

Our very positive findings may also be biased due to the way we selected standards: the first selection criterion were sales figures, in order to be able to explore societal dimensions. Indeed, we found many of them but this may not apply to all standards. Here further research is needed. However, the fact that technical standards developed for business reasons did also have relevance for societal dimensions suggests that this applies to many standards.

Beyond the specific potential impacts identified in the pre-study, we also find a clear link between standards effects and the SDGs, as a globally accepted framework for societal impact classification. This is relevant in the context of the societal debates that motivated the project overall: It suggests that standards can indeed fulfil an important function in addressing major challenges for society. The in-depth case studies (Chapters 6 and 7) build on this observation, and investigate this (potential) role of standards in more detail.

6 In-depth case studies: findings

In this chapter, we summarise our eight in-depth case studies of standards' impacts. Each study relies on qualitative data collected and analysed by master students from Rotterdam School of Management, Erasmus University. The students' studies were conducted under supervision of Prof. Dr. Ir. Henk J. de Vries and Dr. Doyoung Eom during internships at the XXM members. Subsequently, the students' analyses were verified by the entire project team (see Section 2.2.2).

Table 9 provides an overview of the case's key characteristics. Sections 6.1 to 6.6 discuss our findings regarding each standard. Sections 6.7 and 6.8 briefly summarise two case studies where the available evidence was insufficient for an in-depth analysis.

Table 9: Overview over in-depth case studies

Case	Challenge addressed by the standard	Identified impact
ISO 14155: Clinical investigation of medical devices for human subjects (Finland) (p.44)	Ensuring good practice in clinical trials of medical devices	Positive, but incremental in context of regulation and other standards
ISO 14064-1: Quantification and reporting of greenhouse gas emissions and removals (Sweden) (p.48)	Guaranteeing accurate accounting of greenhouse-gas emissions	Limited positive impact, standard may be abused for greenwashing
ISO/IEC 27001:2013: Information security management (Denmark) (p.53)	Managing risks associated with cybersecurity threats	Positive at organisations implementing the standard, implemented at small share of organisations
EN 16516:2017+A1:2020: Assessment of emissions of construction products (Finland) (p.58)	Providing accurate insights into emissions of harmful substances affecting indoor air quality	Positive, through relationship with M1 certification scheme
ISO 17088: Compostable plastics (Sweden) (p.62)	Transforming plastics waste into useable products	Limited implementation, impact direction depends on how standard is applied and resolving technical challenges
ISO 14044: Life-cycle assessment in the construction sector (Norway) (p.68)	Estimating construction materials' impacts on the environment	Limited positive impact
ISO 22397: Societal security (Austria) (p.74)	Supporting collaboration between emergency response organisations	None, due to lack of implementation
ISO 19650-2: Information management in the construction sector (Norway) (p.78)	Increasing effectiveness and efficiency of construction projects	None, recently developed standard which is not yet fully implemented

6.1 ISO 14155: Clinical investigation of medical devices for human subjects (Finland)

This section summarises the results of an in-depth case study of ISO 14155's societal impacts, which was carried out in January-June 2022 in Finland by master student Bibi Leander. It is based on interviews with 17 stakeholders of the standard and relevant documentation. [28]

6.1.1 Introduction to ISO 14155

ISO 14155, *Clinical investigation of medical devices for human subjects — Good clinical practice* was developed by ISO/TC 194 in collaboration with CEN/TC 206 (ISO, 2020). The current, third edition, which we studied, was published in 2020, following earlier versions in 1996, 2003, and 2011.

Challenge, aims & objectives

The standard addresses the challenge that medical devices need to be safe, and their benefits need to outweigh any risks to human health. It contributes to resolving this challenge by defining good practice in clinical investigation of medical devices. It covers principles and processes for designing, conducting, recording and reporting clinical investigations, and addresses clinical studies' ethical aspects. Figure 13 shows which parts of the medical device research process the standard addresses in doing so.

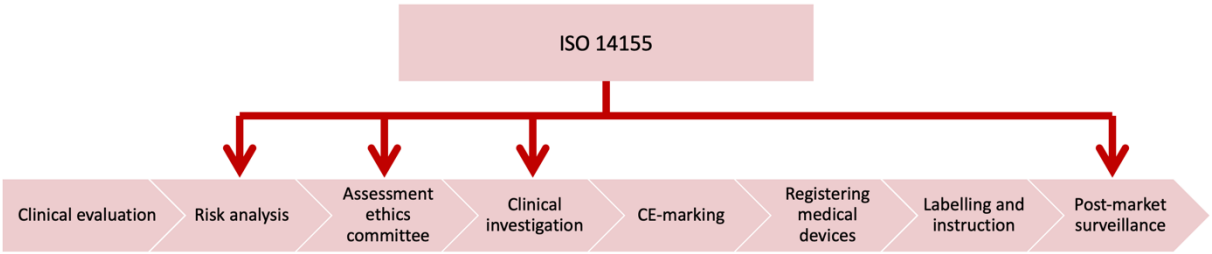

Figure 13: Scope of ISO 14155 within the medical device research process

Links to regulation

Medical devices in the European market are regulated by the Medical Device Regulation (MDR) (European Commission, 2017b). The MDR sets requirements for medical devices and the clinical studies of these devices, which must be met for accessing the European market. EN ISO 14155 (the European version of ISO 14155) is expected to get harmonised under this directive by 2024, if not earlier.[29] This means that carrying out clinical trials in line with the standards will lead to a 'presumption of conformity'. In Finland, the MDR is supported by the Medical Devices Act 719/2021 (MDA). Furthermore, Finnish law regulates clinical trials' ethical aspects.

Outside Europe, the U.S. Food, Drug, and Cosmetic Act (FD&C Act) is very relevant for the standard. The FDA considers results of clinical investigations conducted outside the U.S.

[28] We sent a questionnaire to 102 buyers of the standard in Finland, Norway, and the Netherlands. Five buyers filled in the questionnaire completely, and eleven completed it partly. This is insufficient for a quantitative analysis, but provides us with some additional qualitative insights.

[29] The standard was previously harmonised under the Medical Device Directive, which was replaced by the MDR.

based on ISO 14155 as acceptable clinical data for market approval in the U.S. (U.S. Food and Drug Administration, 2020). Similarly, the Australian government recognises studies conducted under ISO 14155 as acceptable for introducing new medical devices in its market (Therapeutic Goods Administration, 2021).

Relationships with other standards

The standard is aligned with the European Commission Guidelines on Good Clinical Practice and guidance from the U.S. Food and Drug Administration (FDA) (Naden, 2020). Furthermore, ISO 14155 refers to ISO 14971 on risk management for medical devices, although interviewees pointed towards a lack of coherence between both standards.

6.1.2 Key stakeholders of ISO 14155

We identified the following key stakeholder groups:

- Medical device producers,
- Consultancy firms and Contract Research Organisations (CROs) that support clinical investigations,
- Notified bodies in charge of conducting conformity assessments,
- Organisations where clinical trials take place (e.g., hospitals),
- Ethics committees reviewing clinical investigations,
- Regulators of medical devices,
- Participants of the clinical investigations,
- Patients who eventually use the medical devices.

In the Finnish context, some stakeholder groups are represented by a few influential organisations. Notified bodies offering certification according to the MDR are SGS Fimko Oy and Eurofins Expert Services Oy. The Finnish Medicines Agency Fimea is the national authority for regulating pharmaceuticals and medical devices. Ethics committees are responsible for reviewing clinical investigations. In Finland, National Committee on Medical Research Ethics, Tukija, is the national ethics committee and regional ethics committees are established at the Helsinki University Hospital and Turku University Hospital.

6.1.3 Logic model of ISO 14155

Figure 14 on p.46 shows the logic model of ISO 14155's impacts. Where applicable, we group observations according to the key stakeholders (see Section 6.1.2). We discuss the model's implications in Section 6.1.4.

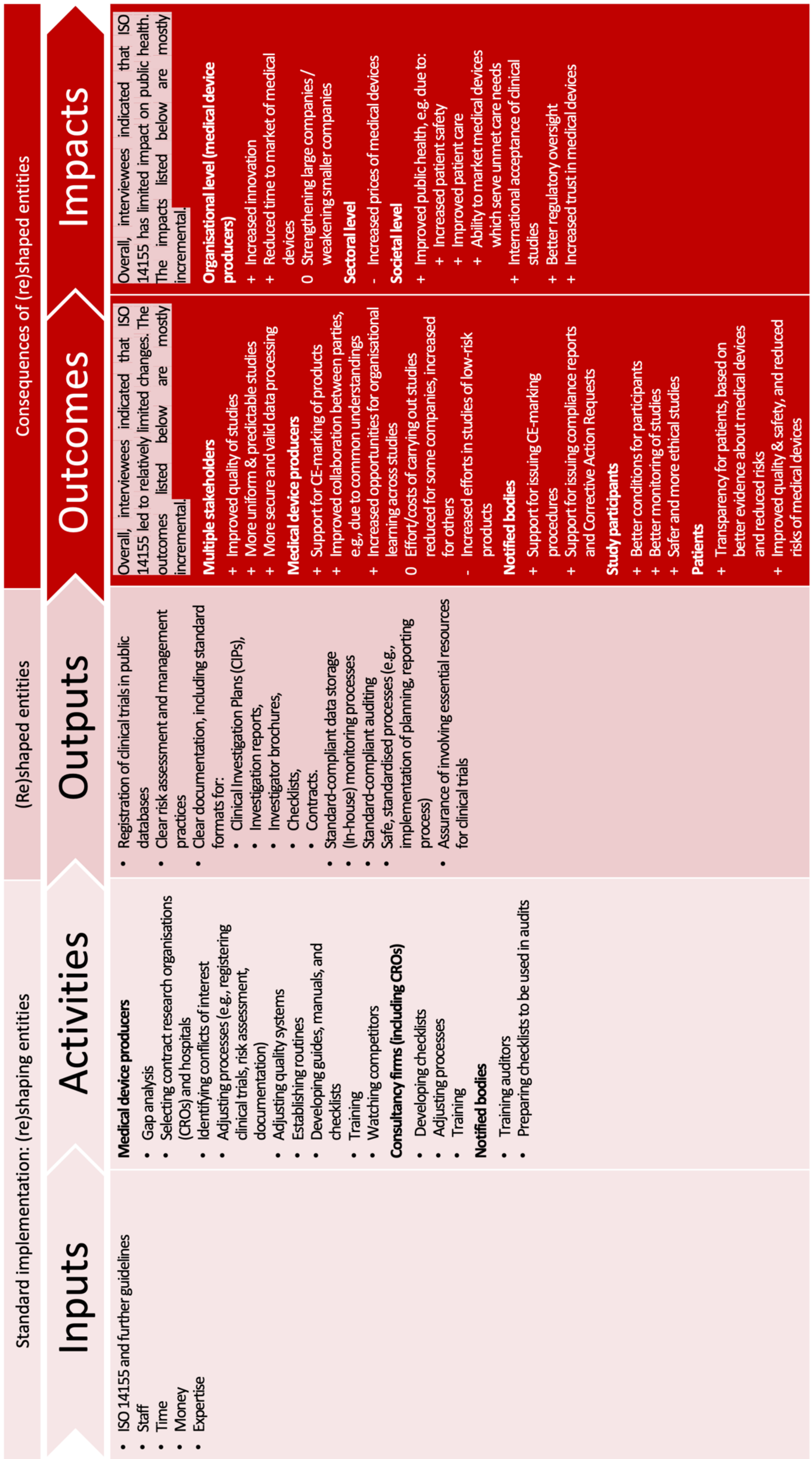

Figure 14: Logic model of ISO 14155's impacts (clinical trials)

6.1.4 Discussion: impacts of ISO 14155

The impacts of ISO 14155 observed in Finland are positive for medical device producers implementing the standard and are also expected to be positive at the societal level. The standard contributes to patient safety and public health, although its impact is incremental in the context of legislative safeguards, other standards, etc. The standard's main functions relate to establishing organisational processes in line with 'Good Clinical Practice' (GCP) principles.

Existing research suggests that using standardised methodologies and protocols in clinical trials provide accuracy, improve reproducibility, and allow better comparisons of data (Hosseinpour et al., 2022). On the other hand, using standards can be time consuming and may not include specific or recently developed test methods (Hosseinpour et al., 2022). The findings of our case study in Finland suggest that the positive outcomes including data accuracy, reproducibility, and comparability and the negative outcomes such as higher costs and efforts are evident as identified in the literature.

ISO 14155's relationship with the MDR and Finnish law, and its support for conformity assessment contribute to its positive impacts. Medical device producers use the standard to support compliance with European regulation. Although, in principle, its application is voluntary, many actors see the standard's implementation as de-facto mandatory because legislation and notified bodies refer to it. This contributes to medical devices obtaining CE marking and entering the European market more quickly than they could, based on a non-standardised approach. EU regulation therefore promotes using the standard and enhances its positive impacts.

The Finnish MDA is harmonised with the MDR and provides exhaustive ethics principles, but does not refer to ISO 14155. In line with this, Finnish ethics committees do not use the standard to assess clinical trials. Different understandings of the standard may therefore cause conflicts between ethics committees and manufacturers. However, ethics committees acknowledge that all actors aim to protect human health, meaning that such potential conflicts are likely to be minor. In countries where national law does not regulate ethics aspects as extensively, the guidance for ethics committees in Annex G of the standard may be relevant.

Acceptance of clinical studies based on the standard for market entry in countries outside Europe (e.g., in the U.S. and Australia, see Section 6.1.1) further enhance its positive impacts. ISO 14155 helps streamline the global market entry process across countries, which accept it as equivalent to their own approaches to clinical trials or have implemented it directly into their legislative frameworks. This ensures that clinical trials carried out in different countries deliver comparable results.

In addition to the impacts related to the standard's legal status, it has potential economic benefits and impacts on innovation. Clinical studies may help understand devices and their effects on patients better, which may lead to discovering new needs and improving devices. However, the extensive requirements for clinical trials may make the process challenging for small companies. This may reduce opportunities to reach patients with innovative devices. Ultimately ISO 14155 contributes to innovative and safe medical devices reaching the

market. It therefore has a positive effect on public health, although interviewees cautioned that its contribution in the grand scheme of things may be relatively small: There are limitations in associating ISO 14155 to positive impacts on patient safety and public health. Other standards (e.g., ISO 14971 on risk management for medical devices) also relate to its societal impacts. Finnish stakeholders specifically pointed to a lack of coherence between ISO 14155 and ISO 14971, as it is unclear how to include risk management in ISO 14155.

6.1.5 Conclusion: relating ISO 14155's impacts to the SDGs

ISO 14155's *primary impact* is on SDG 3 (*"Good Health and Well-Being"*). The standard contributes to achieving this SDG in at least two ways:

1. It supports availability of safe, effective, and innovative medical devices.
2. It minimises risks to the well-being and safety of participants and staff in clinical trials.

Beyond this, our results suggest that ISO 14155 has *secondary impacts* on other SDGs:

1. It supports innovation in the health sector (SDG 9, *"Industry, Innovation and Infrastructure"*)
2. Its links to regulation help ensure transparent and fair procedures for market access of medical devices. In doing so, the standard also supports achieving the "essential requirements" and other policy objectives underlying the MDR and similar international regulation. It therefore contributes to the "governance" and "strong-institutions" aspects of SDG 16 (*"Peace, Justice and Strong Institutions"*).

Our case study therefore shows that the societal impacts of the standard go beyond the ones previously identified by ISO (2022c), which only relates ISO 14155 to SDG 3. However, in the bigger picture its contribution to these SDGs is relatively incremental as there are many other factors (e.g., regulation, established practices in the medical field) which also contribute to the observed impacts.

6.2 ISO 14064-1: Quantification and reporting of greenhouse gas emissions and removals (Sweden)

This section summarises the results of an in-depth case study of ISO 14064-1's societal impacts, which was carried out in January-June 2022 in Sweden by master student Larissa van der Zee. It is based on ten interviews with stakeholders of the standard, a questionnaire with responses from 21 organisations using the standard in Austria, Denmark, Finland, Norway, and the Netherlands, and relevant documents.[30]

6.2.1 Introduction to ISO 14064-1

ISO 14064-1:2018, *Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals* was developed by ISO/TC 207, SC 7 (ISO, 2018a). The current, second edition, which we studied was published in 2018, following an earlier version in 2006.

[30] We sent a questionnaire to 401 buyers of the standard in Austria, Denmark, Finland, Norway, and the Netherlands. Seven buyers filled in the questionnaire completely, and nine completed it partly. This is insufficient for a quantitative analysis, but provides us with some additional qualitative insights.

Challenges, aims & objectives

Global warming, caused by greenhouse-gas (GHG) emissions, is one of the most substantial threats to both mankind and nature. The standard contributes to addressing this challenge by supporting organisations in accounting for their GHG emissions. It requires them to identify and quantify direct and indirect GHG emissions and removals, specifies how to establish a GHG inventory, and supports selecting and using quantification methodologies.[31] It also requires information management procedures for organisations' GHG inventories.

Links to regulation and policy

The Kyoto Protocol[32] and the European Union's Emission Trading Scheme (ETS) are important elements of ISO 14064-1's context. The standard can be used for validating and verifying organisations' emissions for the ETS (ISO, 2019a). However, the Swedish Environmental Protection Agency considers other standards, which focus on specific production sites instead of entire organisations, as more relevant for ETS purposes (source: personal communication).

Relationship with other ISO and non-ISO standards

ISO 14064-1 is part of the ISO 14060 family of GHG standards. This family provides a coherent approach for "quantifying, monitoring, reporting and validating or verifying GHG emissions and removals" (ISO, 2018a, p. vi). Figure 15 provides an overview of the standards of this family and how they are related to each other.

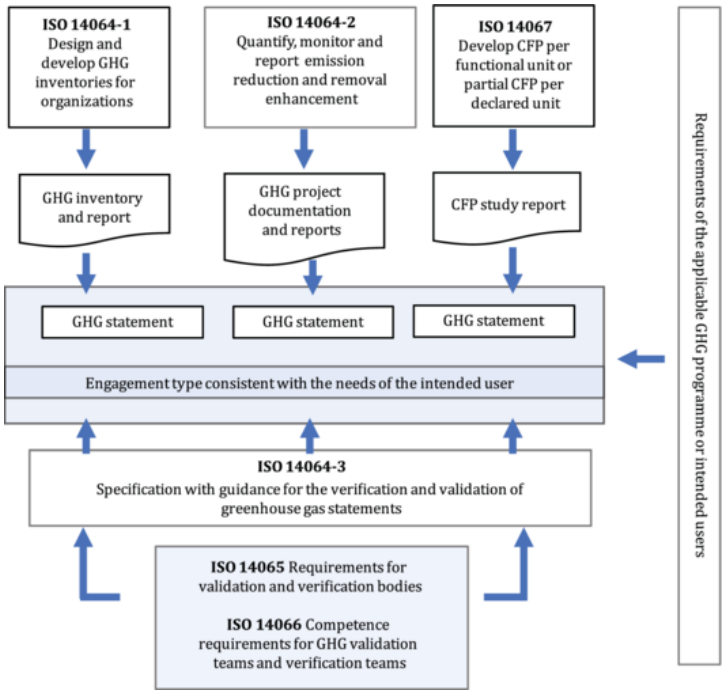

Figure 15: Relationships among the ISO 14060 family of GHG standards (source: ISO, 2018a, p. viii)

Furthermore one of the GHG Protocol standards (*"The Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard"*), which was developed by the World

[31] The standard does not prescribe a specific methodology for estimating GHG emissions and removals, but "recommends" using the latest Intergovernmental Panel on Climate Change (IPCC) global warming potential (GWP) values.

[32] This international treaty was signed in 1997, and commits states to reduce GHG emissions.

Resources Institute and WBCSD (World Resources Institute and WBCSD, 2022),[33] is relevant for our study. Important parts of ISO 14064-1 are based on this standard. It is the most widely used approach to GHG accounting and was developed before the ISO standard (Harangozo and Szigeti, 2017; Hickmann, 2017). Some, including interviewees in our study and Matisoff et al. (2013), characterise the GHG Protocol as competing with ISO 14064-1, whereas others conclude that "though different in a few minor areas, the protocol and the ISO standard are complementary documents" (Wintergreen and Delaney, 2006, p. 3). The GHG Protocol details *how to account* for GHG emissions, whereas ISO 14064 sets *minimum requirements for reporting*, without detailing specific methods (Klopsch, 2022; Matisoff et al., 2013; Wintergreen and Delaney, 2006).

6.2.2 Key stakeholders of ISO 14064-1

We identified the following key stakeholder groups:

- Production companies,
- Consultancy firms,
- Universities,
- Parties which make use of reporting, including customers, authorities and NGOs.

6.2.3 Logic model of ISO 14064-1

Figure 16 on p.51 shows the logic model of ISO 14064-1's impacts. Outcomes of the standard mostly apply at the level of organisations using the standard for taking stock of their GHG emissions. We also found that the standard is somewhat vague in its requirements. For example, it leaves substantial freedom about which emissions to include in a GHG report. This may lead to misunderstandings or intentional misuse, the consequences of which are shown at the bottom of Figure 16.

[33] Similar to the ISO 14060 family, the GHG Protocol is a family of standards. *"The Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard"* is the counterpart to ISO 14064-1. In the subsequent text, we refer to this standard when we use the term "GHG Protocol".

	Standard implementation: (re)shaping entities		(Re)shaped entities	Consequences of (re)shaped entities	
	Inputs	**Activities**	**Outputs**	**Outcomes**	**Impacts**

	• ISO 14064-1
	• Staff (if specialised experts are available in-house) and/or consultants
	• Time
	• Money
	• Expertise
	• Reporting software
	• Administrative resources
	• Information from management systems (environmental management system, possibly also quality management system)
		• Preparing for GHG reporting according to ISO 14064-1 (potentially supported by 3rd parties, such as consultants and auditors)), including:
		  • Establishing quantification methodologies
		  • Establishing data management procedures
		• Establishing cooperation within the organisation for access to data
		• Training
			• Procedures for GHG reporting established, e.g.:
			  • Quantification approach for GHG emissions and removals
			  • GHG inventory approach
			  • GHG report format
			  • Process for periodical reporting
			• Data collected and used for quantification
				Organisational level
				+ Ability to report GHG emissions and removals, e.g. as:
				  + Dedicated GHG reports
				  + Element of annual reports
				  + GHG databases
				+ Improvements related to GHG mitigation:
				  + Easier identification of mitigation opportunities
				  + Enhanced tracking of mitigation progress
				  + Support for organisational decision making on GHG mitigation
				+ Improved communication and transparency on GHG emissions towards external stakeholders, leading to:
				  + Improved access to financing based on better information for investors
				  + Enhanced credibility and environmental integrity
				  + Increased consistency in communication
				- Increased GHG management- and reporting costs
				- Risk of green-washing
				- Tunnel vision on GHG mitigation, limited consideration of other environmental issues
					Organisational level
					+ Stronger focus on GHG mitigation
					  + Increase in GHG mitigation projects
					  + Participation in GHG initiatives
					  0 Increased investments required for GHG mitigation
					+ Changes in relationships with external stakeholders
					  + Increased trust of stakeholders
					  + Supply-chain adaptation
					  + Improved partnerships related to GHG
					  + Stronger client-awareness of GHG issues → may lead to them taking further action on GHG emissions
					Sectoral level
					  + Increased innovation and diffusion of low-emission technologies
					  + GHG-related policy changes
					Societal level
					+ Climate change mitigation
					+ Reduction of GHG impact on human health

Misuse / misunderstanding	• Ambiguities in ISO 14064-1, leaving substantial freedom in implementing the standard (e.g., concerning which GHG to report)			- Inaccurate GHG statements, based on only parts of the relevant GHG inventory
				- GHG reports not meeting (all) requirements of the standard
					- Misuse of the standard (narrow inventory boundaries) and/or tunnel vision leading to:
					  - Delayed climate action,
					  - Misleading those who rely on ISO 14064-1 based reporting

Figure 16: Logic model of ISO 14064-1's impact (GHG reporting)

6.2.4 Discussion: impacts of ISO 14064-1

Impacts of ISO 14064-1 are positive for society, as the standard supports organisations which want to take action to mitigate GHG emissions. We expect that our findings are generalisable beyond Sweden because there are no country-specific elements in the logic model. Quantifying and reporting based on the standard helps organisations understand their GHG emissions, providing insights for decision-making and helping communication with external stakeholders. Cumulatively, organisations applying the standard may contribute to societal targets of reducing GHG emissions.

While the standard's effects are thus in principle positive, our study identified two factors, which may limit this impact:

1. Ambiguities in the standard, which may give rise to (un)intentional misuse, ultimately resulting in "greenwashing",
2. The relationship with the GHG Protocol.

Below, we discuss these factors in more detail.

Ambiguities in the standard

Some interviewees perceive ISO 14064-1 to be vaguely formulated. Moreover, the standard leaves freedom to choose which emissions to include in GHG inventories and reports.[34] Organisations' GHG reports may thus be inaccurate, intentionally or due to misinterpretations of the standard.[35] Our interviewees had no concrete examples of inaccurate GHG statements based on ISO 14064-1, but they perceived this as a substantial risk. Using the standard may thus possibly support "greenwashing", especially if it is implemented in response to external pressures (see Section 6.2.5), and thus negatively affect the standard's support for GHG mitigation. It may also mislead customers, authorities, and other stakeholders who rely on GHG reports.

Relationship with the GHG Protocol

While some see the GHG Protocol and ISO 14064-1 as complementary to each other (Klopsch, 2022; Wintergreen and Delaney, 2006), some interviewees in our study saw them as competing alternatives. In this 'standards battle', the GHG Protocol has some advantages: (1) It became available first and many organisations had already implemented it. (2) Its free availability promotes market acceptance. (3) It is considered more accessible as the document contains graphs, case examples, guidance, and more actionable guidelines (Klopsch, 2022; Matisoff et al., 2013). It is the dominant standard in this field (Harangozo and Szigeti, 2017; Hickmann, 2017; Robinson et al., 2018). ISO 14064-1 was developed despite the committee being aware of the GHG Protocol. The New Work Item Proposal (NWIP) identifies a gap to be addressed by ISO 14064-1. However, its similarity with the GHG Protocol raises questions about whether this gap actually existed and ISO 14064-1 was needed as a new standard. The existence of multiple standards may create confusion in the market, as is evident from Klopsch's (2022) contribution. This may deter from the aim of supporting GHG mitigation.

[34] According to Wintergreen and Delaney (2006), the same applies to the GHG Protocol. Some interviewees confirmed this.

[35] See the bottom part of Figure 16 on p.51.

Due to the substantial overlap between ISO 14064-1 and the GHG Protocol, several interviewees could not clearly distinguish the two standards. The ISO standard's impacts (see Figure 16) can also be achieved with the GHG Protocol. This limits our study in establishing the counterfactual situation without ISO 14064-1 because the GHG Protocol was already established when the ISO standard was introduced.

6.2.5 Conclusion: relating ISO 14064-1's impact to the SDGs

ISO 14064-1's *primary impact* relates to SDG 13 (*"Climate Action"*). Our study shows that the standard has potential to contribute to this SDG if it is used as intended. However, its ambiguous relationship with the GHG Protocol calls into question to what extent it actually contributes to achieving this SDG. Furthermore, its vagueness may open it up to misuse, which may actually lead to setbacks in achieving SDG 13.

In addition to its primary target, ISO 14064-1 may also have *secondary impacts* on several other SDGs:

1. By stimulating investment in eco-innovations, the standard may contribute to SDG 9 (*"Industry, Innovation and Infrastructure"*) and the sustainability aspects of SDG 11 (*"Sustainable Cities and Communities"*).
2. By raising awareness for companies GHG footprint, the standard may stimulate consumers to make more environmentally conscious choices. This may in turn incentivise investments in more environmentally-friendly production processes (SDG 12, *"Responsible Consumption and Production"*).
3. If the standard succeeds in contributing to reduced GHG emissions, this may benefit SDGs 14 (*"Life Below Water"*) and 15 (*"Life on Land"*).

These potential secondary impacts are subject to the same caveats as the standard's primary impact (i.e., they may be neutral or even negative, depending on how the standard is used).

Previous research supports the concerns about the standard potentially having negative impacts: Many organisations' sustainability reporting, including reports based on ISO 14064-1, contains misleading information (Boiral and Heras-Saizarbitoria, 2020). In particular if organisations are forced to improve their sustainability by investor or market demands, they may resort to greenwashing to improve their legitimacy (Delmas and Burbano, 2011). Environmental underperformers may try to change stakeholders' perceptions by additional reporting (Cho et al., 2012; Gray et al., 1995).[36] In line with our observation that the standard's vagueness may facilitate this, Boiral and Heras-Saizarbitoria (2020, p. 12) call for sustainability reporting standards to "be much more specific in terms of expertise, verification processes, and expected outcomes".

6.3 ISO/IEC 27001:2013: Information security management (Denmark)

This section summarises the results of an in-depth case study of ISO/IEC 27001:2013's societal impacts, which was carried out in January-June 2022 in Denmark by master student Maaike van der Waal. It is based on nine interviews with stakeholders of the standard, a

[36] Even though Neumann (2021) found that such "symbolic greening strategies" do not pay off, at least for start-ups.

questionnaire with responses from 47 organisations using the standard in Denmark, Finland, and the Netherlands, and relevant documents.

6.3.1 Introduction to ISO/IEC 27001

ISO/IEC 27001, *Information technology — Security techniques — Information security management systems — Requirements* was developed by ISO's and IEC's joint technical committee JTC 1. The second edition, which we studied, was published in 2013, following an earlier version in 2005. After our study was conducted, the standard was replaced by a third edition in October 2022.

Challenge, aims & objectives

The standard addresses Information Security Management System (ISMS). Such systems are increasingly relevant because of cybersecurity challenges, such as preventing cyberattacks, safeguarding organisations' ICT systems and digital assets, and protecting individuals' data. The standard specifies "requirements for establishing, implementing, maintaining and continually improving an ISMS" (ISO/IEC JTC 1, 2013, p. 1).

Links to regulation and policy

The European General Data Protection Regulation (GDPR) poses extensive requirements for handling personal data in the EU (European Commission, 2016). ISO/IEC 27001 directly addresses some key requirements of the GDPR, thus supporting firms' compliance (Diamantopoulou et al., 2020). Consequently, this is an important motivation for implementing the standard for many participants in our study, although the GDPR and ISO/IEC 27001 are not formally linked.

As part of the Danish national Strategy for Cyber and Information Security, all Danish government agencies must implement ISO/IEC 27001 (Danish Government, 2021). This also motivates many private companies in Denmark to implement the standard.

Relationships with other standards and certification

ISO/IEC 27001 was adopted by Danish Standards as the national standard DS-EN-ISO/IEC 27001. During the interviews we learned that the Danish translation of the standard is inaccurate. For example, the key term "control" was translated into "measuring" in Danish although the standard does not limit "controls" to the act of measuring, auditing, etc. Instead, the standard specifies that "controls" should be in place to guide protection of information assets (ISO/IEC JTC 1, 2013). These mistranslations have implications for implementation and impacts in Denmark, as we discuss in Section 6.3.4.

The standard is part of the ISO/IEC 27000 family, which encompasses more than a dozen standards related to ISMS (ISO, 2022d). While ISO/IEC 27001 lays down generic requirements for ISMS, other standards in the family provide, e.g., further guidance for implementation, applications in specific industry sectors, and requirements for audits and certification. Organisations with ISMSs according to ISO/IEC 27001 may get certified following an audit by an accredited third party.

The standard applies ISO's High-Level Structure on Management System Standards (HLS). The HLS aligns management system standards (e.g., ISO 9001, ISO 14001) so that

organisations can seamlessly operate integrated management systems that meet the requirements of multiple standards (ISO, 2022e).

Some organisations implement ISO/IEC 27001 together with other standards, especially if they have international operations. NIST 800-53 (NIST, 2020) is used globally and is compulsory for federal agencies in the U.S. The Center for Internet Security's (CIS), a community-driven non-profit organisation, developed 18 'Critical Security Controls' (Center for Internet Security, 2021) which are also widely used.

6.3.2 Key stakeholders of ISO/IEC 27001

We identified the following key stakeholder groups:

- Organisations implementing ISMS (our data include retailers, organisations in the healthcare and telecommunications sectors, and governmental organisations),
- Software companies,
- Consultancy firms,
- Certification bodies,
- Stakeholders who rely on the information systems based on ISO/IEC 27001 such as customers and citizens.

6.3.3 Logic model of ISO/IEC 27001

Figure 17 on p.56 shows the logic model of ISO/IEC 27001's impacts. Where applicable, we group observations according to the key stakeholders (see Section 6.3.2). We discuss the model's implications in Section 6.3.4.

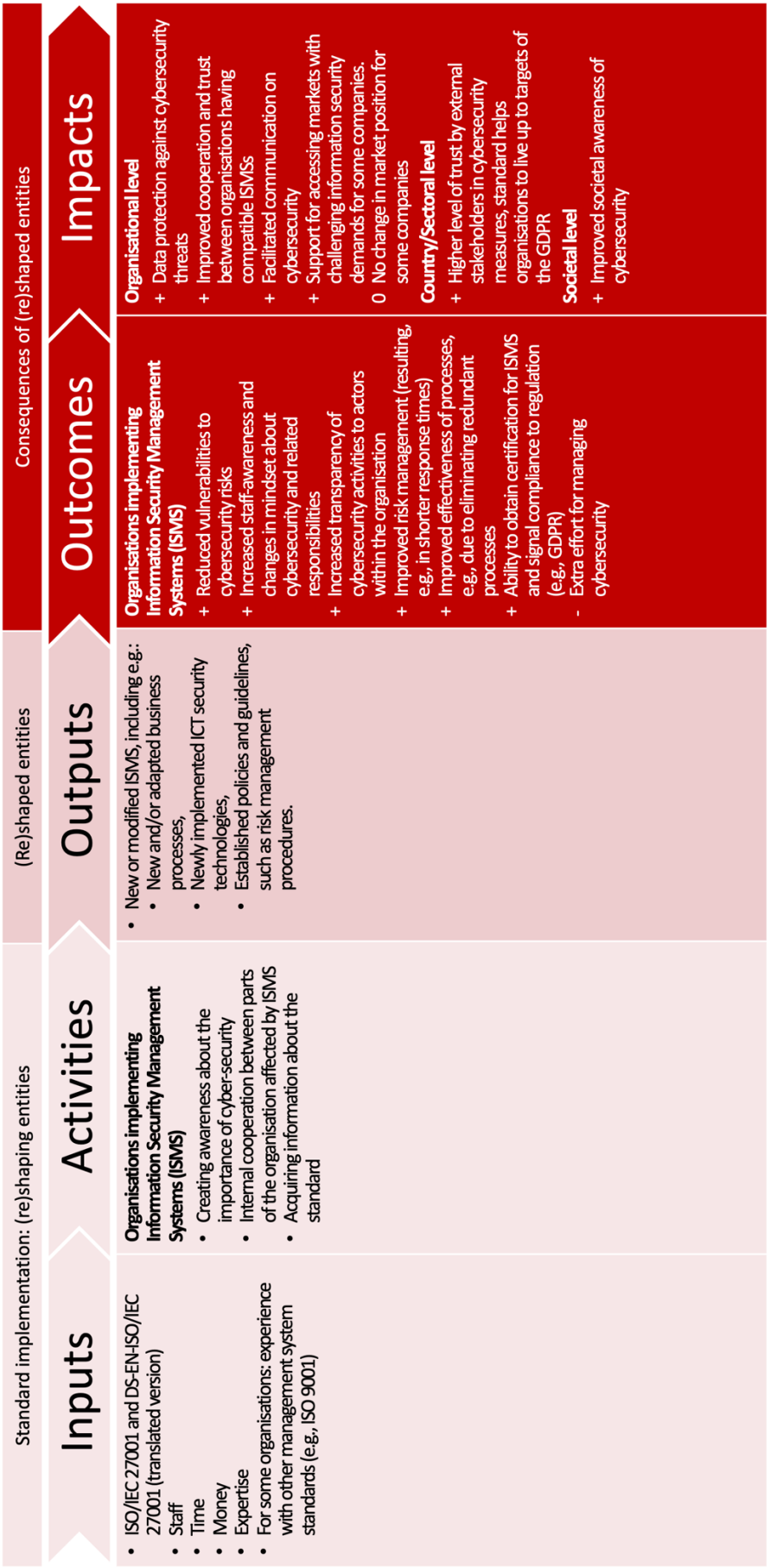

Figure 17: Logic model of ISO/IEC 27001's impacts (information security management)

6.3.4 Discussion: impacts of ISO/IEC 27001

Impacts of ISO/IEC 27001 in Denmark are positive for organisations implementing the standard and are expected to be positive for society as a whole. This is due to three main factors: (1) ISMSs designed according to the standard tend to be more effective in addressing cybersecurity threats. (2) Legislation (GDPR and Danish Strategy for Cyber and Information Security) augments the need for ISMSs. (3) Subsequent certification augments the standard's effects. Below, we discuss these factors in more detail.

Modifying or newly establishing ISMSs requires organisations to change, e.g., technologies, policies, and business processes. ISO/IEC 27001 guides them in doing so in a way that they can better manage cybersecurity risks and secure information assets. Implementing the standard leads to positive outcomes and impacts, such as increased awareness among staff and support for accessing markets with high demands for information security. These outcomes and impacts may differ depending on the implementation's scope and organisation size. An organisation may only implement parts of the standard, use it as a reference, or apply it only at some departments. In particular, implementing the standard is more challenging for SMEs. This is especially caused by the High-Level Structure in the standard's latest version, which facilitates implementation at companies with ISO-9001-based quality management systems, but makes it more difficult at others. In addition, the inaccurate Danish translation may lead to different outputs than intended by the standard's creators.

In the Danish context, we identified two legislation-related effects on ISO/IEC 27001's impacts:

1. Mandatory implementation for governmental organisations is specific to Denmark,[37] and promotes the standard's implementation. This may also potentially encourage private-sector organisations to adopt the standard.
2. The standard's role in conjunction with the GDPR applies across Europe. This provides an additional motivation for organisations to implement the standard, as it supports them in complying with legal requirements.

ISO/IEC 27001 certification leads to further positive outcomes. It demonstrates compliance and reassures customers that a company meets internationally accepted standards for data security (also see van Wessel and de Vries, 2013).

Although our findings point towards ISO/IEC 27001 having positive impact in Denmark, its effects are also relatively limited due to a small share of private Danish companies implementing it. 493 Danish companies received an ISO/IEC 27001 certificate between 2013 and 2021[38] and Danish Standards has been selling on average 100 copies of the standard per year since 2013. Thus, only a fraction of the more than 320,000 companies in Denmark (Statistics Denmark, 2020) appear to use the standard. Information security management is

[37] Other countries, such as the Netherlands, have similar policies.

[38] We use certification as a proxy for estimating the number of companies, which have implemented the standard.

relevant for almost all organisations,[39] meaning that there remains much room for amplifying ISO/IEC 27001's positive impacts in Denmark. However, the standard's market share among critical-infrastructure organisations in Denmark (including governmental organisations) is high. It therefore plays an important role in reducing vulnerabilities, mitigating threats related to cybersecurity and protecting critical infrastructure at the country level. Its relevance is further enhanced by standards which were derived from ISO/IEC 27001,[40] although these standards are outside the scope of our study.

6.3.5 Conclusion: relating ISO/IEC 27001 to the SDGs

ISO/IEC 27001's *impacts primarily* relate to the resilience aspect of SDG 9 (*"Industry, Innovation and Infrastructure"*), as it helps organisations reduce their vulnerability to cyberattacks. Our study suggests that the standard is effective at doing so for the organisations which implement it.

Furthermore, our results suggest that ISO/IEC 27001 has *secondary impact* on additional SDGs in Denmark. This impact primarily relates to the standard's mandatory implementation by governmental organisations, meaning that it supports them in contributing to the SDGs in their specific field of work (e.g., healthcare – SDG 3; education – SDG 4; maintaining critical infrastructures for water, energy, and in cities – SDGs 6, 7, and 11). In doing so, the standard also contributes to strengthening Denmark's public institutions (SDG 16).

6.4 EN 16516:2017+A1:2020: Assessment of emissions of construction products (Finland)

This section summarises the results of an in-depth case study of EN 16516:2017+A1:2020's societal impacts, which was carried out in January-June 2022 in Finland by master student Janne Hesen. It is based on ten interviews with stakeholders of the standard, and relevant documents.[41]

6.4.1 Introduction to EN 16516

EN 16516, *Construction products: Assessment of release of dangerous substances – Determination of emissions into indoor air* was developed by CEN/TC 351 (CEN/CENELEC, 2022) under Mandate M/366 (CEN, 2020). The first edition was published in 2017. We studied the current second edition, which was published in 2017, and its amendment in 2020.

Challenge, aims & objectives

The standard addresses the challenge of harmful substances being emitted into indoor air by construction products, which causes both health and environmental problems. It contributes to solving this challenge by specifying a reference method for determining the extent of

[39] The standard may be unsuitable for SMEs and micro-organisations because it may place a too heavy burden on them. Several countries developed guides for SMEs' cybersecurity efforts, which are complementary to ISO/IEC 27001.

[40] Examples include ISO/IEC 27701 (*"Security techniques – Extension to ISO/IEC 27001:2019"*), and ISO/IEC 27002 (*"Privacy information management – requirements and guidelines"*).

[41] We sent a questionnaire to 80 buyers of the standard in Austria, Finland, Norway, and the Netherlands. Four buyers filled in the questionnaire completely, and two completed it partly. This is insufficient for a quantitative analysis, but provides us with some additional qualitative insights.

these emissions. The standard specifies a reference room for testing samples and the testing process, including steps like sampling products, procedures for analysing dangerous substances, calculating emission rates, and reporting.

National context of Finland

The challenges addressed by this standard are particularly relevant in the Finnish context. The Finnish working-age population is estimated to spend more than 90% of its time indoors, children and the elderly even more (Finnish Institute for Health and Welfare, 2022). The conditions under which harmful emissions can emerge and spread indoors are affected by factors, such as temperature, moisture, and air flows. Furthermore, wood is a popular building material in Finland. Some wood-based products, such as particleboards, can emit formaldehyde (e.g., due to glue in these products). These factors contribute to a high awareness about indoor-air quality in Finnish society, and have made Finland a forerunner in research and providing guidance about indoor air quality (Lampi et al., 2020). In line with this, the Finnish Institute for Health and Welfare has launched the Finnish Indoor Air and Health Programme 2018-2028, which aims to improve a range of health indicators related to indoor air in this period (ibid.).

Links to regulation

Construction products in the European market are regulated by the Construction Product Regulation (CPR) (European Commission, 2011). The European Commission (2022b) lists EN 16516 as a 'horizontal specification' under this regulation. The CPR sets basic requirements for construction products, which determine whether a product may be sold on the European market. One of these basic requirements relates to emissions of dangerous substances, which may cause neither a health hazard nor harm the environment. However, the CPR does not lay down specific performance criteria, such as maximum levels of emissions. These performance criteria remain to be decided by the member states. Some European countries, including Finland, have national legislation that focusses on indoor air quality (Settimo et al., 2020).

Relationships with other standards and certification schemes

Many consumers in the Finnish market place great importance on the 'M1 Classification' (see Building Information Foundation RTS, 2022), which classifies and labels building products according to their emissions of harmful substances. The standard underlying this classification sets limit values for emissions of Volatile Organic Compound (VOC), formaldehyde, and ammonia. It specifies that products' emissions should be measured using the methods and procedures laid down in EN 16516, and is aligned with other ISO standards and the EU-LCI values (Building Information Foundation RTS, 2017).

6.4.2 Key stakeholders of EN 16516

We identified the following key stakeholder groups:

- Producers of construction products or materials,
- Laboratories that carry out testing according to this standard,
- Occupants of buildings.

6.4.3 Logic model of EN 16516

Figure 18 on p.61 shows the logic model of EN 16516's impacts. We group observations according to the key stakeholders (see Section 6.4.2). We discuss the model's implications in Section 6.4.4.

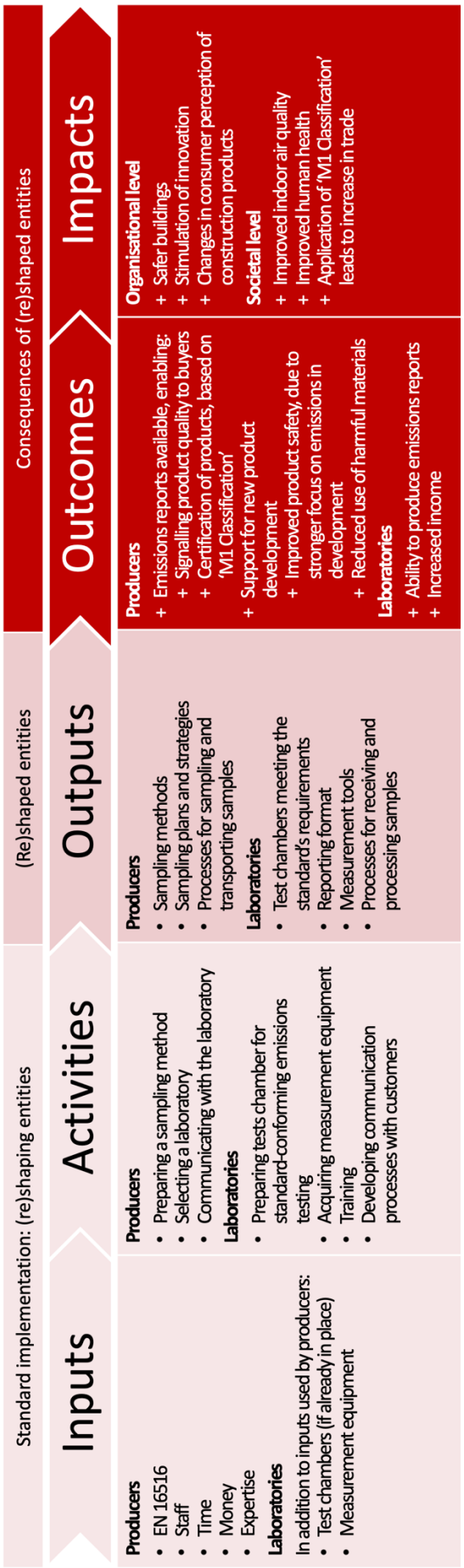

Figure 18: Logic model of EN 16516's impacts (emissions of construction products)

6.4.4 Discussion: impacts of EN 16516

EN 16516 addresses a clear need in the Finnish market that made its implementation a success story. Factors unique to Finland make good indoor air quality a significant consideration for large parts of the population and for policymakers (see Section 6.4.1).

Key to this success has been the standard's link to the M1 Classification. While the classification scheme is voluntary, it has emerged as a de-facto standard, and the label is an important marketing tool. EN 16516 is the foundation for emission testing and certification under the scheme, and thus contributes to M1's potential positive impacts. By promoting sales of low-emissions construction products, the M1 Classification contributes to cleaner indoor air and better human health. The Finnish Indoor Air and Health Programme uses the FinHealth Survey and the National Indoor Air and Health Survey to measure changes in the prevalence of health issues associated with indoor environments (Lampi et al., 2020). The results of these studies are not yet available, but may provide evidence of the M1 Classification's effects.

There is currently no uniform approach to addressing indoor air quality across European countries. Germany, France, and Belgium regulate indoor air quality in their building codes. Other countries, such as the Netherlands, developed guides for maximum permissible levels of pollutants, which have no legal status. The special situation of EN 16516 underlying the M1 de-facto standard limit our findings' generalisability. Factors, such as certification's importance, market acceptance of certified products, and enforcement of regulation may affect the standard's impacts in other contexts.

6.4.5 Conclusion: relating EN 16516 to the SDGs

EN 16516 is a very targeted standard, which addresses a relatively narrow technical problem. This problem corresponds to a clear need in the Finnish market, and the standard underlies an influential certification scheme. Due to these two factors, the standard has well-traceable impact on a clearly scoped societal area.

The standard's *primary impact* is on SDG 3 (*"Good Health and Well-Being"*) through its contribution to a healthy indoor environment. *Secondary impacts* relate to it stimulating innovation of cleaner construction products and buildings (SDG 9, *"Industry, Innovation and Infrastructure"*; SDG 12, *"Responsible consumption and production"*).

6.5 ISO 17088: Compostable plastics (Sweden)

This section summarises the results of an in-depth case study of ISO 17088's societal impacts, which was carried out in January-June 2022 in Sweden by master student Meihui Jiang. The study is based on twelve interviews with stakeholders of the standard and relevant documentation.[42]

6.5.1 Introduction to ISO 17088

ISO 17088:2021, *Plastics — Organic recycling — Specifications for compostable plastics* was developed by ISO/TC 61 (ISO, 2021a). The current third edition, which we studied, was published in 2021, following earlier versions in 2012 and 2008.

[42] Out of 28 buyers of the standard in Austria, Finland, and the Netherlands, who we contacted with a questionnaire, none responded. We could therefore not use questionnaire data in this study.

Challenges, aims & objectives

Plastics pollution is a pressing problem to the global environment and causes serious harm to human health. There are increasing societal demands for recovering plastics by transforming waste into usable products or composts. The standard contributes to solving this challenge by specifying requirements and test procedures for plastics that are suitable for organic recycling in industrial composting facilities. It requires that plastic materials are biodegradable, and plastics or the compost do not contain harmful substances and provides test methods to assess this (ISO, 2021a).

National context of Sweden

The Swedish climate is less suitable for composting processes which require high temperatures, and there are few composting facilities in the country. Sweden therefore faces constraints in industrial composting of plastics and implementing ISO 17088. Nevertheless, SIS adopted the standard without modifications as a national standard (SIS, 2021).

Links to regulation and policy

The standard itself has no direct links to regulation. However, in Europe, packaging materials (which are an important use of compostable plastics) are regulated by the Packaging and Packaging Waste Directive (European Commission, 2022c; European Parliament and Council of the European Union, 1994). The directive's essential requirements for composting and biodegradable packaging address its compatibility with other materials in composting facilities and the composition of finished compost. Furthermore, the standard is relevant for the European Plastics Strategy, which relates the topic to policies on the circular economy, and the Paris Climate Agreement (European Commission, 2022d, 2018).

Relationships with other standards and certification schemes

Other standards overlap with ISO 17088 in terms of testing requirements and criteria, and pose similar requirements in terms of biodegradability and toxicity of the composted materials. In the European context, EN 13432 for packaging is particularly relevant, also because it is seen as "the father of all other standards in the field" (TÜV Austria, n.d.). It is harmonised under the Packaging and Packaging Waste Directive (European Commission, 2022e), meaning that implementing it results in a 'presumption of conformity' with the directive's essential requirements.

Other relevant standards include the following:

- EN 13432 covers compostable packaging made of any material, including plastics. It is also used for plastics applications other than packaging, and competes with ISO 17088.
- EN 14995 covers compostable plastics which are not used for packaging.
- ISO 18606 specifies procedures and requirements for organic recycling of packaging, regardless of the used materials.
- Outside Europe, ASTM D6400 (USA), AS 4736 (Australia), and CAN/BNQ 0017-088 (Canada) address compostable plastics. The latter is based on ISO 17088 with modifications for the Canadian context (BNQ, 2010).

A key difference between ISO 17088 and other standards (e.g., EN 13432, ASTM D6400) is that the former requires earthworm tests for determining the harmful effects of compost on terrestrial organisms.

Most standards for compostable plastics and packaging, including ISO 17088 and EN 13432, have related certification schemes. Under these schemes, third-party certification bodies (e.g., DIN Certco, TÜV Austria, Vinçotte) certify that plastics materials or products comply with the standard underlying the scheme. Certified plastic materials and products may carry labels, such as the "OK Compost" label, which signal to consumers that they are compostable.

6.5.2 Key stakeholders of ISO 17088

We identified the following key stakeholder groups:

- Producers of plastics materials,
- Producers of plastics products,
- Companies in the plastics supply chain (e.g., trading plastics products, using plastics in packaging),
- Applied research institutes and academia,
- Testing organisations,
- Certification bodies,
- Composting facilities,
- NGOs working on environmental protection,
- Government and public administration,
- Consumers and their associations.

6.5.3 Logic model of ISO 17088

Figure 19 on p.65 shows the logic model of ISO 17088's impacts. Where applicable, we group observations according to the key stakeholders (see Section 6.5.2). Due to the Swedish climate's constraints for plastics composting (see Section 6.5.1), many of the outcomes and impacts in the logic model may not materialise. Furthermore, the widespread use of EN 13434 may mean that some outcomes and impacts are also driven by this standard. We discuss the model's implications in Section 6.5.4.

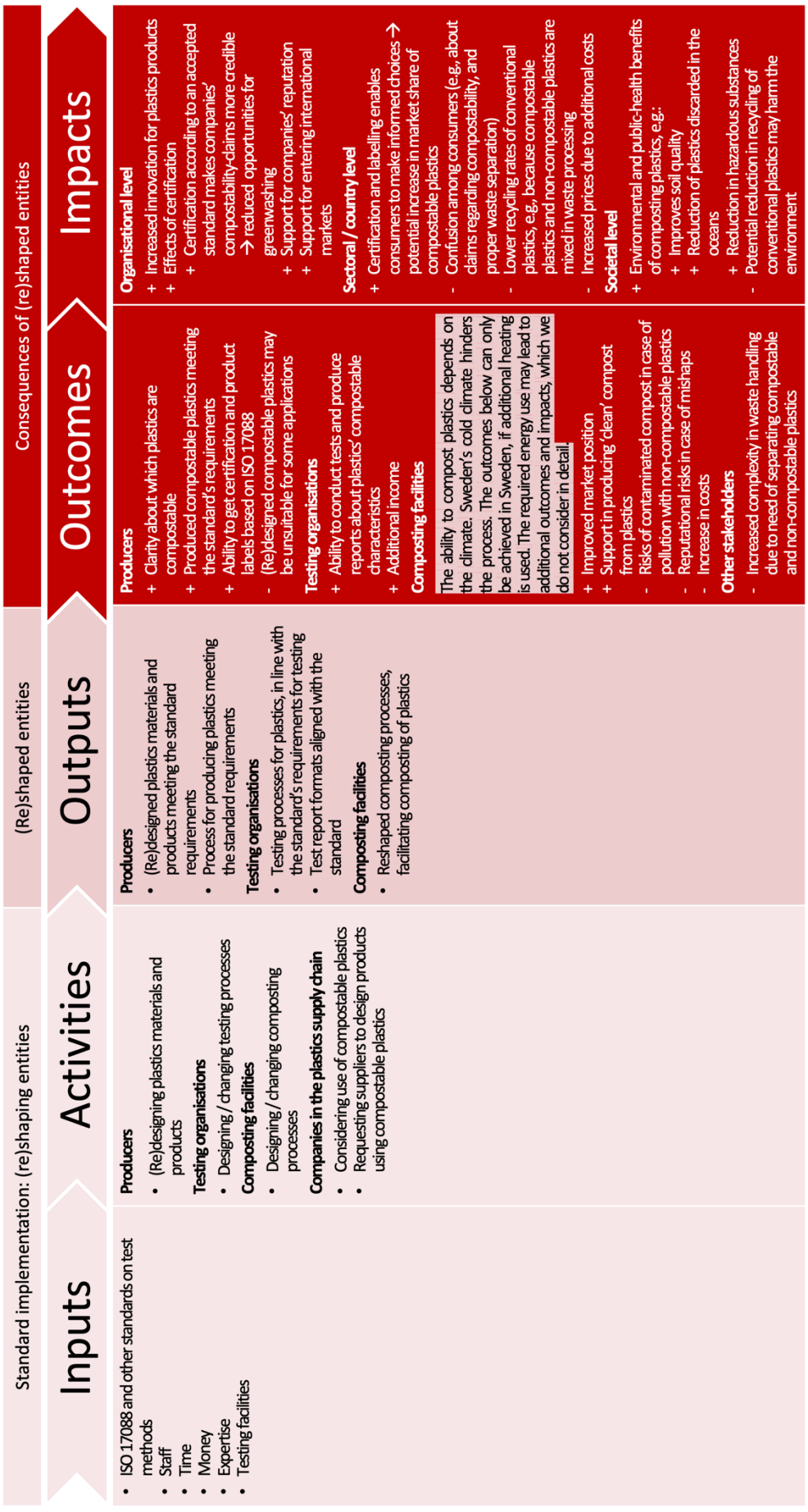

Figure 19: Logic model of ISO 17088's impacts (compostable plastics)

6.5.4 Discussion: impacts of ISO 17088

ISO 17088 can potentially impact society positively if it contributes to an increasing share of plastics being compostable and eventually being turned into composts. However, this depends on a number of factors. In the Swedish context, the standard is only applied on a small scale under laboratory conditions by testing organisations. Based on our interviews, we identified three key factors affecting ISO 17088's implementation:

1. Suitable composting facilities and climate conditions,
2. Lack of consumers' awareness and their waste-disposal practices,
3. Decisions by large players in the plastics supply chain.

Below, we discuss these issues in more detail.

Composting facilities and climate conditions

Sweden lacks composting facilities to process compostable plastics waste. It shares this issue with many other countries, such as the U.S. and China (Jia, 2020), and only 5.5% of waste is currently composted globally (Kaza et al., 2018). Large-scale use of compostable plastics would require a substantial increase in composting capacity. Particularly in cold countries, this is a challenge. Our interviews revealed that Sweden's cold climate inhibits large-scale composting processes. Running these processes in cold countries would therefore require substantial amounts of energy to heat facilities or transport waste to warmer climates, which would negatively affect compostable plastics' overall environmental balance.

Consumer awareness and waste-disposal practices

Consumers may be confused about claims of plastics being "compostable", and may thus be unaware of how to properly dispose of plastic waste. Interviewees criticised ISO 17088's terminology, which identifies composting as a type of recycling.[43] This terminology is also used in communication with consumers, whereas referring to the " bio-waste bin/residual container" would communicate more clearly how compostable plastics should be disposed. This may lead to consumers disposing compostable plastics in the recycling system and/or conventional plastics in compostable-plastics containers. Both damages the environment: Processing compostable together with conventional plastics disturbs the recycling process, whereas adding conventional plastics to composting processes leads to (potentially hazardous) waste entering the biosphere. An interviewee at a composting plant reported that the latter is a regular problem in practice.

As outlined in Section 6.5.1, there are several standards and certification schemes, which all pursue similar goals. Certification schemes and their labels are based on different standards, and may be inconsistent in what they communicate to consumers. This further adds to consumers' confusion about disposing the products (Fogh Mortensen et al., 2021). In the context of missing composting facilities, certifying plastics as "compostable" may also give rise to wrong consumer-expectations about plastics' environmental impact.

Decisions by large players in the plastics supply chain

When interviewing a major Sweden-based retailer, which uses large amounts of plastics globally, we learned that decisions to use compostable plastics are embedded in a wider

[43] This terminology is already evident from the standard's title.

context. Compostable plastics are not always considered the most sustainable alternative. For example, they may not be used in the following situations:

1. Specific applications (e.g., food packaging) may pose requirements that cannot be met by compostable plastics,
2. Other materials (e.g., paper) may be used to replace plastics altogether,
3. Priority may be given to reducing the amount of plastics (e.g., by reducing packaging volumes), instead of changing materials.

Nevertheless, compostable plastics may support sustainability in other situations. For instance, we learned about a case where a product was re-designed using compostable plastics. In this case, the material's properties mean that the product can also be re-used more often before it needs to be discarded by composting. In applications where plastics are contaminated by food waste, compostable materials may be preferable. While food waste disturbs 'traditional' recycling processes, it can be naturally decomposed in composting facilities.

6.5.5 Conclusion: relating ISO 17088 to the SDGs

Due to the limited production of bioplastics, and the lack of composting facilities, ISO 17088's impact on the SDGs is still small. Following application on a larger scale, its *primary impact* will concern SDGs 12 (*"Responsible Consumption and Production"*). The standard can also have *secondary impacts* on SDGs 6 (*"Clean Water and Sanitation"*), 14 (*"Life Below Water"*), and 15 (*"Life on Land"*), if it affects the amount of plastic waste that is released into the environment.

Our results suggest that the application area of bioplastics plays a role in determining whether these impacts will be positive or negative. In some applications (e.g., where alternative, less polluting, materials are available), applying compostable plastics may negatively affect these SDGs. In other applications, compostable plastics may be the preferred alternative and may have positive impact. For this positive impact to be possible, challenges related to consumer awareness and proper disposal of plastics need to be addressed. These conditions are not yet met in Sweden, i.e., potential environmental benefits are not reaped.

Climate conditions in cold countries remain a particular challenge for the widespread implementation of ISO 17088. In the worst case, the standard may also negatively affect SDG 13 (*"Climate Action"*) if substantial amounts of energy are used for heating composting facilities or transporting plastic waste to warmer environments. This issue should be addressed in future revisions of the standard, reflecting the state of the art. If current compostable-plastics technology does not facilitate composting at colder temperatures, this may also be a relevant innovation challenge for plastics producers. [44]

[44] Canada shares its cold climate with Sweden. The Canadian adapted version of ISO 17088 (CAN/BNQ 0017-088, see Section 6.5.1) may make the composting process more suitable for cold climates. Investigating whether this is the case was beyond the scope of our study, and is a relevant question for future research.

6.6 ISO 14044: Life-cycle assessment in the construction sector (Norway)

This section summarises the results of an in-depth case study of ISO 14044's societal impacts in the construction sector, which was carried out in January-June 2022 in Norway by master student Daniele Barresi. The study is based on ten interviews with stakeholders of the standard, as well as relevant documentation.[45]

6.6.1 Introduction to ISO 14044

ISO 14044:2006, *Environmental management — Life cycle assessment — Requirements and guidelines* was developed by ISO/TC 207, SC 5. The current, first edition, which we studied, was published in 2006 and remains current following its last review in 2022 and amendments in 2017 and 2020.

Challenge, aims & objectives

Society increasingly expects organisations and their products/services to be sustainable and minimise any negative environmental impacts. In this context, life cycle assessment (LCA) aims to systematically analyse these impacts across a product's life from raw-material acquisition all the way to its disposal. The standard supports these efforts by providing general guidelines for LCA methodologies, which can be used when carrying out the assessment (ISO, 2006). The standard does so by specifying a methodological framework and requirements for processing LCA results, covering six aspects:

1. Defining an LCA's goals and scope,
2. Conducting life cycle inventory analysis (LCI),
3. Conducting life cycle impact assessment (LCIA),
4. Life cycle interpretation,
5. Reporting,
6. Critical review processes.

Focus on the Norwegian construction sector

While ISO 14044 is not sector-specific, this study focusses on the Norwegian construction sector. This sector accounts for the largest share of the standard's buyers in Norway. Due to an increasing awareness of buildings' environmental impacts, LCA tools have proliferated in the construction sector (Nwodo and Anumba, 2019). The standard's popularity in this sector is driven by a high demand for Environmental Product Declarations (EPDs) (Andersen et al., 2019). EPDs rely on generally accepted LCA methods, and are labels which disclose products' life-cycle environmental performance. Furthermore, the construction sector has a longer history of applying LCA and EPDs than other Norwegian industries, meaning that its practice in the area is relatively well-developed.[46]

Links to regulation and policy

The European Commission has been promoting LCA within its Integrated Product Policy, which aims to reduce products' and services' environmental impact (European Commission, 2022f, 2022g). To support these policy efforts, the European Commission's Joint Research

[45] Out of 376 buyers of the standard in Austria, Finland, the Netherlands, and Norway, who we contacted with a questionnaire, only one responded. We could therefore not use questionnaire data in this study.

[46] Other sectors with advanced implementation of LCA include the food sector, and the electronics industry. Given the different nature of these industries, our findings are unlikely to apply there.

Centre and DG ENV developed the International Life Cycle Data System (ILCD), based on ISO 14044 and ISO 14040 (European Commission, 2022h). In line with this policy support for LCA, a number of European and national regulations require LCA. For example, Norwegian public tenders for construction require bidders to provide LCA results and EPDs to be eligible for participation.

Relationships with other standards

A substantial number of ISO standards address LCA. A recent study identified 54 ISO standards on the topic, with ISO 14040:2006 and ISO 14044:2006 (the standard analysed in this study) being considered the key references for the global LCA community (Toniolo et al., 2019). They provide the foundations for most international LCA standards, with ISO 14040 providing "a more general, introductory reading" and ISO 14044 being "the operational document including all requirements for ISO compliant LCA studies" (Finkbeiner, 2014, p. 94). Based on these standards, the ISO 14040 series includes a number of more specialised standards (ibid.).

In the Norwegian construction sector, the following standards are particularly relevant in the context of ISO 14044:

- *ISO 14025* sets principles and procedures for developing EPDs.
- *ISO 21930* and *EN 15804* provide specific requirements for EPDs of construction products and services.
- *EN 15978* covers the system boundaries of LCA in the construction sector by defining "modules" that can be covered by LCA. These "modules" determine which part of a building material's life is covered by LCA (e.g., Modules A1 to A3 cover the material production stage) (Gervasio and Dimova, 2018).

Relationships with certification schemes

EPDs are often used for building certification systems such as the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) building rating system, the BRE Group's Building Research Establishment Environmental Assessment Method (BREEAM), or the German Sustainable Building Council (DGNB)'s DGNB system (Passer et al., 2015). Many LCAs are thus conducted to obtain EPDs and provide the necessary data for certification. This was a major focus area for our interviewees, and subsequently our analysis.

6.6.2 Key stakeholders of ISO 14044

We identified the following key stakeholder groups:

- Companies producing products or services that are assessed using LCA,
- Consultancy firms,
- Software developers, who provide LCA solutions,
- Parties, who use LCA results.

In addition, we identified two stakeholder groups who are not direct stakeholders of the standard, but are relevant in the wider EPD context:

- EPD verifiers (bodies assigned by the national EPD programme operator[47] to verify EPDs),
- Retailers and wholesalers of construction materials.

6.6.3 Logic model of ISO 14044

Figure 20 on p.71 shows the logic model of ISO 14044's impacts. In line with many stakeholders' foci on EPDs in the Norwegian construction sector, the model revolves around this LCA application. In line with this, the reported outputs, outcomes, and impacts result from the combination of ISO 14044 with other relevant standards for EPD creation.

[47] In Norway: EPD Norge.

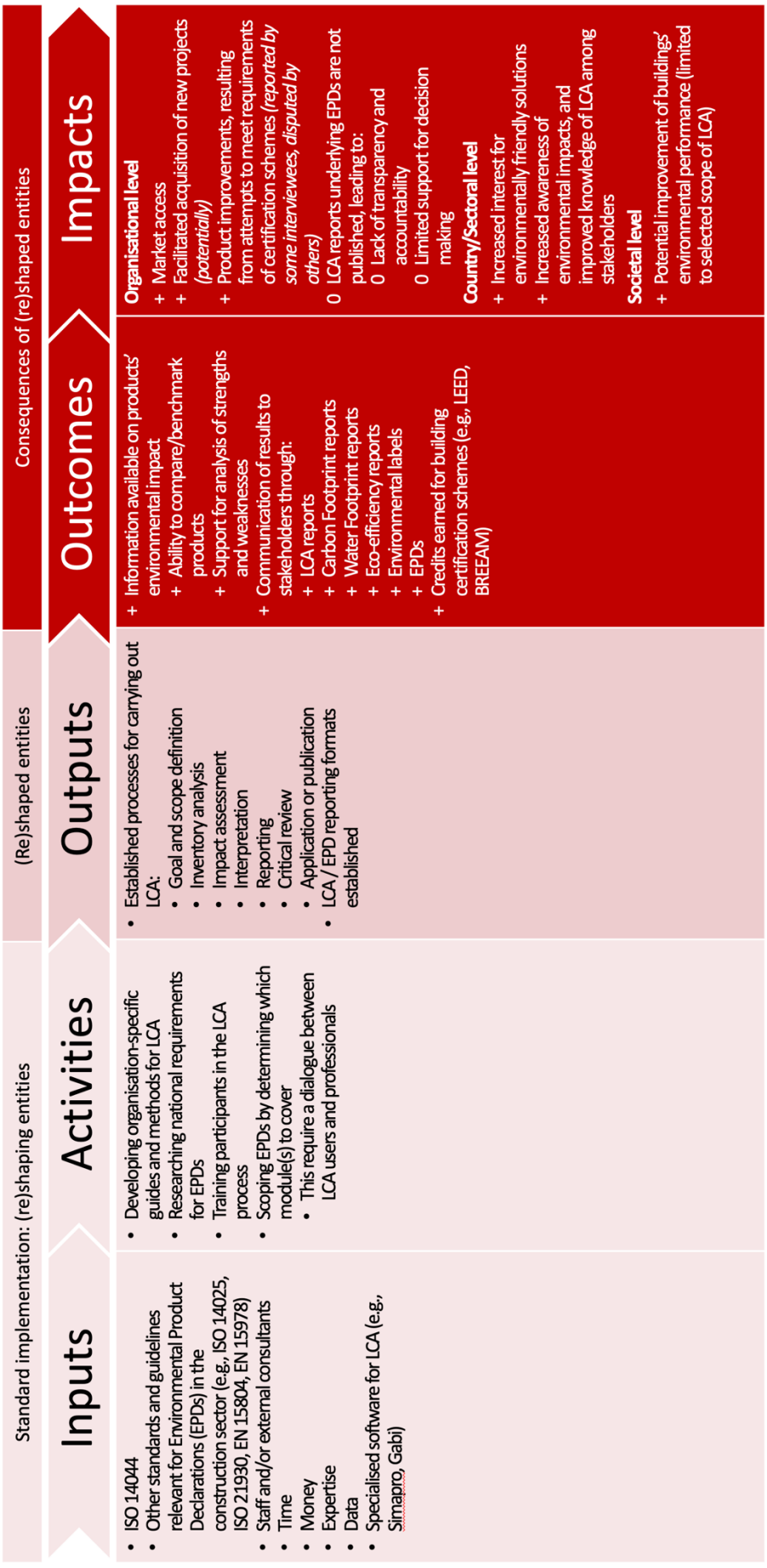

Figure 20: Logic model of ISO 14044's impacts (life-cycle assessment, with focus on EPDs)

6.6.4 Discussion: impacts of ISO 14044 in the Norwegian construction sector

ISO 14044's impact in the Norwegian construction sector to a large extent stems from its function for supporting EPDs, which are increasingly required for market access. In this context, guidelines based on the standard, and other standards (ISO 14025, ISO 21930, EN 15804, EN 15978) also are important.[48] National EPD program operators (e.g., EPD Norge) operate based on this collection of standards. This makes it difficult to isolate ISO 14044's impacts from those of other relevant standards and guidelines.

Based on this, we identify two factors affecting ISO 14044's impact in the Norwegian construction sector:

1. Variation in LCA outcomes and EPDs,
2. Currently suboptimal use of LCA and EPDs.

Below, we discuss these issues in more detail.

Variation in LCA outcomes and EPDs

Both LCA as a practice, and the building sector as a field, are complex. Substantial expertise is therefore needed to carry out LCA. This is reflected in several interviewees mentioning that the subject is taught in university-level courses, and the ability to conduct LCA in-house being concentrated at large companies.[49]

Room for methodological choices in LCA standards, such as the ability to limit assessment on only some parts of a building's life-cycle,[50] or to select specific assessment methods, reflects the field's complexity. It also reflects a lack of global stakeholder consensus (Finkbeiner, 2014). Some therefore criticise ISO 14040 and ISO 14044 for being imprecise and call for a "cookery book" approach (Baitz et al., 2013; Finkbeiner, 2014). In the worst case, this may lead to selective and misleading reporting.

A particular concern relates to many LCAs, including those underlying EPDs, which are conducted without the required uncertainty analysis (Curran, 2014). EPD verification should ensure that only EPDs with all information required by ISO 14025 are published. However, incomplete EPDs frequently pass verification processes (Gelowitz and McArthur, 2017). Interviewees confirmed this also to be the case in Norway.

Arguably, the standard's flexibility accommodates complexities of the building sector. It is also argued that this supports "useful application, information, and result exchange, learning curves, and communication of LCA and its (positive) impact overall" (Baitz et al., 2013, p. 13). However, it also makes practicing LCA more challenging, and may contribute to incomplete LCAs underlying ECDs. Ultimately, methodological differences between LCA studies may hinder comparing results (e.g. Durão et al., 2020). It also has implications for decision-making support. Improper assessment of the data (e.g., inventory data and impact

[48] Many other standards refer to ISO 14044, meaning that aspects of it may also be implemented by buyers of these standards. LCAs may thus still be conducted on the basis of ISO 14044 by practitioners who do not directly refer to its contents.
[49] Smaller companies typically need to rely on consultants.
[50] Based on the modules defined in EN 15978.

assessment indicators) can limit the reliability of the results to support decisions for the product life cycle (e.g., product improvement).

Suboptimal use of LCA and EPDs

Our interviewees highlighted an increasing demand for LCA and EPDs. According to them, this has caused some parties in the industry to shift their thinking about sustainability, but no tangible outcomes have resulted from this. Interviewees revealed specific limitations of LCA's and EPDs' current use in Norway. These concern (1) motivations and incentives to use LCA and EPDs, (2) and them not enabling traceability of individual products. Addressing these limitations may augment LCA's impact in the sector.

Interviewees described the construction industry as a sector, which still has relatively little concern for its environmental impact. In line with this view, many stakeholders see LCA and EPDs as a "necessary evil" to get access to the market, without much added value in itself. In line with the practice's complexity, they may also have a limited understanding of it. One interviewee suggested making the topic more accessible and relevant to the field by linking the outcomes of LCA to easily understandable indicators, such as the amount of CO_2 saved by particular stakeholders. Adding a competitive element may further engage them.

The common LCA focus on Modules A1 to A3 (material production stage) is seen as a further factor limiting its impact, as it does not incentivise stakeholders further down the supply- and use chain to improve their environmental impact. According to a building-material wholesaler, adding traceability of individual products in the supply chain may enable tracking differences in supply-chain footprint. Wholesalers and retailers would be able to use this as a differentiator in competition with each other, which may incentivise them to invest in sustainability.

6.6.5 Conclusion: relating ISO 14044 to the SDGs

It is challenging to disentangle impacts of ISO 14044 from those of the more general EPD and LCA ecosystem in the Norwegian construction sector. Our case study therefore addresses the impacts of the ecosystem. In principle, this system can be expected to improve environmental performance of buildings, by influencing decisions and incentivising investment in green products. In line with this, the system may potentially have *primary impacts* on SDGs 11 (*"Sustainable Cities and Communities"*), 12 (*"Responsible Consumption and Production"*) and the SDGs concerning the environment (SDG 13, *"Climate Action"*; SDG 14, *"Life Below Water"*; SDG 15 *"Life on Land"*), and *secondary impacts* on SDG 9 (*"Industry, Innovation and Infrastructure"*).

Unfortunately, our data suggest that the Norwegian EPD and LCA ecosystem has little actual impact. Limited comparability of LCA outcomes, and suboptimal use of LCA and EPDs in the sector mean that they provide few incentives for stakeholders to adjust what they do. In the worst case, this may even lead to misleading reporting, although we found no evidence of this. Some interviewees identified a shift in thinking in the sector, but this has yet to result in

tangible changes.[51] Altogether, the standard therefore does not live up to its potential impact.

6.7 ISO 22397: Societal security (Austria)

This section summarises the results of an in-depth case study of ISO 22397's societal impacts, which was carried out in January-August 2022 in Austria by master student Jose Luis Sarmiento Fernandez. Unfortunately, insufficient evidence for an in-depth analysis was available for this case. We present an overview over the main findings.

6.7.1 Introduction to ISO 22397

ISO 22397:2014, *Societal security — Guidelines for establishing partnering arrangements* was developed by ISO/TC 292 (ISO, 2014). The current, first edition, which we studied, was published in 2014. The international standard was adopted as EN-ISO 22397:2018 by CEN Technical Committee CEN/TC 391.

Challenges, aims & objectives

Natural and human induced disasters require authorities and other emergency responders to react effectively. As part of such an effective disaster response, national and local authorities need to cooperate and align their activities to protect citizens' health and safety. The standard addresses this challenge by providing processes for establishing partnering arrangements between emergency-response organisations. In this context, it describes planning, developing, implementing, and reviewing processes, and covers formal and informal partnering arrangements (ISO, 2014).

National context of Austria

The standard seems to be of particular interest for Austria due to events in the Ischgl ski resort in March 2020, which were blamed for accelerating the spread of Covid-19 in Europe. An independent commission of experts appointed by the Tyrolean regional government concluded that risks were misjudged and inadequate measures were taken. Particularly, authorities' were found to have failed in acting promptly to shut down the area (Hersche et al., 2020).

Despite the standard's potential relevance for Austria's emergency-response capabilities, it was and still is barely used. There were only nine buyers in the last five years. Almost half of the sales came from libraries and universities. The rest were from consultants, pharmaceuticals, customer protection and insurance.[52] When the standard was reviewed in 2019, Austria abstained from voting, which suggests a lack of stakeholders' interest.

Relationships with other ISO standards

The standard is part of the ISO 22300 family of standards. It refers to ISO 22300 ("security and resilience – vocabulary") , which defines key terms for the family (ISO, 2021b). Despite this reference, a definition of the key-term "societal security" is missing from both ISO 22300 and ISO 22397.

[51] The scope of our research limited us in investigating this further. A future study may shed more light on how thinking in the industry has changed in response to LCA and EPDs.

[52] These low sales figures of the standard are not unique to Austria.

6.7.2 Key stakeholders of ISO 22397

We identified the following key stakeholder groups:

- Police departments,
- Medical organisations,
- Fire departments,
- Municipal authorities,
- Citizens and organisations which may depend on cooperation between emergency responders.

6.7.3 Hypothetical logic model of ISO 22397

We found no traceable use of ISO 22397 or studies that investigate the standard, based on desk research and attempts to contact potential interviewees.[53] While the standard provides input in the logic model, there are no observable implementation activities that would lead to measurable outputs, outcomes, or impacts. We therefore conclude that this standard currently has no societal impact. Figure 21 on p.76 shows a hypothetical logic model of the impacts that the standard may be expected to have if it was implemented.

[53] No buyers of the standard or committee members of ISO/TC 292 agreed to be interviewed. We conducted five interviews with other stakeholders.

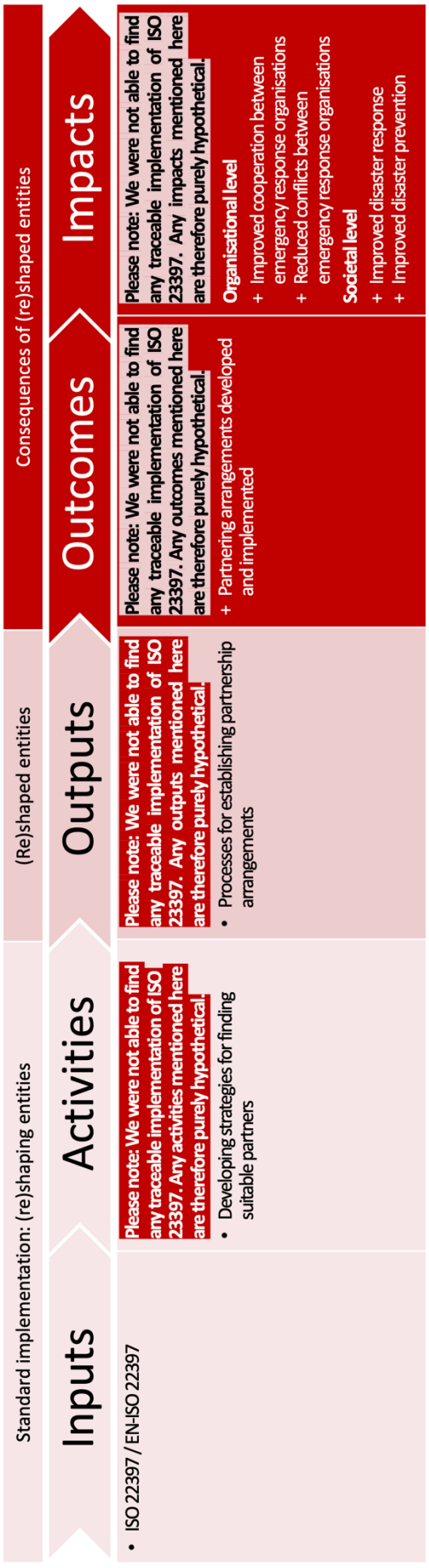

Figure 21: Hypothetical logic model of ISO 22397's impacts (societal security)

6.7.4 Discussion: reasons for the lack of ISO 22397's impact

The standard is not used in Austria and we found no indication of use in other countries. We aimed to find the reasons for the standard's lack of implementations and impact. We identified five factors, which may explain this:

1. Prevalence of established partnership-building practices without the standard,
2. Lacking awareness of the standard,
3. Costs of buying and implementing the standard,
4. Issues in the standard's clarity,
5. Structural changes in the standardisation process.

We examined the New Work Item Proposal (NWIP) based on which ISO 22397 was developed to find what problem the standard intended to solve. According to the NWIP, there is a gap because no standards give "details or guidelines" for establishing public-private partnerships. However, interviewees saw no need for the standard because of well-established processes for establishing partnerships. Managers and lawyers routinely do so without guidance from a standard. Established partnership-building processes are considered satisfactory, meaning that the need identified in the NWIP was not recognised by potential users of the standard in Austria.

Furthermore, we found a lack of awareness of the standard. Several committee members of ISO/TC 292 indicated that they have no knowledge of ISO 22397 or partnerships for societal security when we approached them for an interview. Members in the Austrian mirror committee (TC 246) also lacked awareness of the standard's contents. Three out of five of them reacted positively to what the standard aimed to achieve when the researcher provided an excerpt to them. Out of six Austrian buyers, only two responded that they knew of the standard.

The costs for purchasing and implementing the standard is a barrier. It is already well known that costs are one of the barriers for SMEs in obtaining and implementing standards (Blind and Gauch, 2009; de Vries et al., 2009). This applies to key Austrian stakeholders, which are mostly volunteer-driven organisations for whom the costs do not outweigh the perceived benefits in light of established partnership-building practice.

We also identified issues with the standard's clarity and readability. Following an interviewee's comment about lacking clarity, we applied the Flesch Reading Ease test (Didegah and Thelwall, 2013). The readability score places the standard in the "very hard to read" category. The standard may therefore need an overhaul to make its content clear to potential users.

Finally, structural changes to ISO's technical committees added confusion. ISO 22397 was published during a transition period when three committees were merged into ISO/TC 292 in June 2014. This structural change transformed a homogenous committee into one covering various topics, which are not at the core of societal security. Meanwhile, the relevant committees of ISO, CEN and ASI have different names and scope.[54] This results in confusion

[54] ASI's mirror committee is named *"Societal Security"*, the CEN committee is named *"Societal and Citizen Security"*, and the ISO committee is named *"Security and Resilience"*.

about the scope of standardisation for societal security, and hinders marketing and sales. In this setting, a review of the standard in 2019 did not change it, and also did not lead to withdrawal, despite its lack of use.

6.7.5 Conclusion: relating ISO 22397 to the SDGs

Despite its potential to address important societal issues, such as the Austrian authorities' failure in addressing the Covid-19 outbreak in Ischgl (see Section 6.7.1), the standard is not used in Austria. It therefore does not contribute to reaching the SDGs. A well-designed and used standard for partnership in societal security might potentially support a number of SDGs, including SDG 3 (*"Good Health and Well-Being"*), SDG 11 (*"Sustainable Cities and Communities"*), and SDG 17 (*"Partnership for the Goals"*).

6.8 ISO 19650-2: Information management in the construction sector (Norway)

This section summarises the results of an in-depth case study of ISO 19650-2's societal impacts, which was carried out in January-August 2022 in Norway by master student David Doelman. It is based on 13 interviews with stakeholders of the standard, and relevant documents.

6.8.1 Introduction to ISO 19650-2

ISO 19650-2:2018, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 2: Delivery phase of the assets* was developed by ISO/TC 59 (ISO, 2018b). The current, first edition, was published in 2018.

Challenges, aims & objectives

Many countries experience a housing crisis, which increases the need for housing and infrastructure. The construction sector needs more efficient, cost-effective, and safer methods for designing and managing building projects to deal with this challenge. ISO 19650-2 contributes to this by specifying requirements for Building Information Modelling (BIM) in the delivery phase. BIM is defined as the "use of a shared digital representation of a built asset to facilitate design, construction and operation processes" (ISO, 2018c). It defines a management process to support information management between the parties involved in a building project (e.g., construction companies, architects, clients) during the delivery phase (ISO, 2018b; Winfield, 2020). Figure 22 shows the standard's scope.

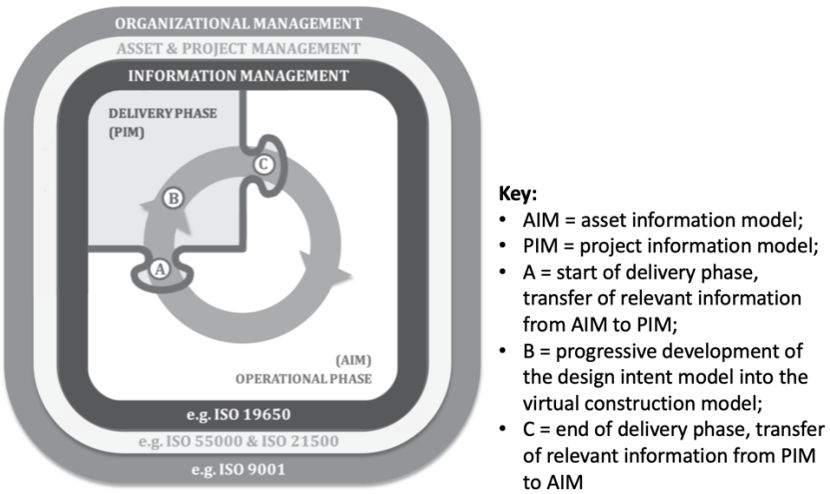

Figure 22: Scope of ISO 19650-2:2018 (source: ISO, 2018b, p. 6)

National context of Norway – national standards and use of ISO 19650

The Norwegian Directorate of Public Construction and Property, Statsbygg, has developed guidelines for BIM. Its BIM manual SIMBA was launched in 2008. All parties in supply chains of public construction projects should follow one of the four versions (Statsbygg, 2022a). The most recent version (SIMBA 2.1) refers to ISO 19650-2: It requires that agreement on BIM is reached based on NS-EN ISO 19650-2 in a construction project's offer phase (Statsbygg, 2022b). Earlier SIMBA versions did not refer to the standard.

Relationship with other international standards

The standard is part of the ISO 19650 family, which is still being developed. [55] Other standards in the series provide concepts and principles (ISO 19650-1:2018), specify information management in the operational phase (ISO 19650-3:2020), information exchange (ISO 19650-4:2022) and a security approach (ISO 19650-5:2020). In the context of asset & project management, the standard refers to two further standards: (1) ISO 55000 on asset management and (2) ISO 21500 on project, programme and portfolio management (see Figure 22).

ISO 19650 parts 1 and 2 were developed based on the British standard BS 1192:2007+A2:2016 (BSI, 2007) and the Publicly Available Specification PAS 1192-2:2013 (BSI, 2013). The main differences between ISO 19650 and the 1192 suite of standards are changes in terminology and an added list of vital activities to achieve efficiency in the information management process (Winfield, 2020).

6.8.2 Key stakeholders of ISO 19650-2

We identified the following key stakeholder groups:

- Architecture firms,
- Engineering companies,
- Construction companies,
- Governments,
- IT companies,
- Consultancy firms.

6.8.3 Hypothetical logic model of ISO 19650-2

Due to ISO 19650-2's recent development, it is still too early to empirically determine results of implementing the standard. Construction, architect, and engineering companies have not implemented the standard yet, or only implemented it recently (e.g., in 2021). We therefore conclude that the standard does not yet have societal impact. Figure 23 on p.80 shows a hypothetical logic model of the impacts that the standard may be expected to have once it is implemented. In addition to our own analysis, we base the logic model on research by Winfield (2020).

[55] ISO 19650-6 on health and safety is still under development.

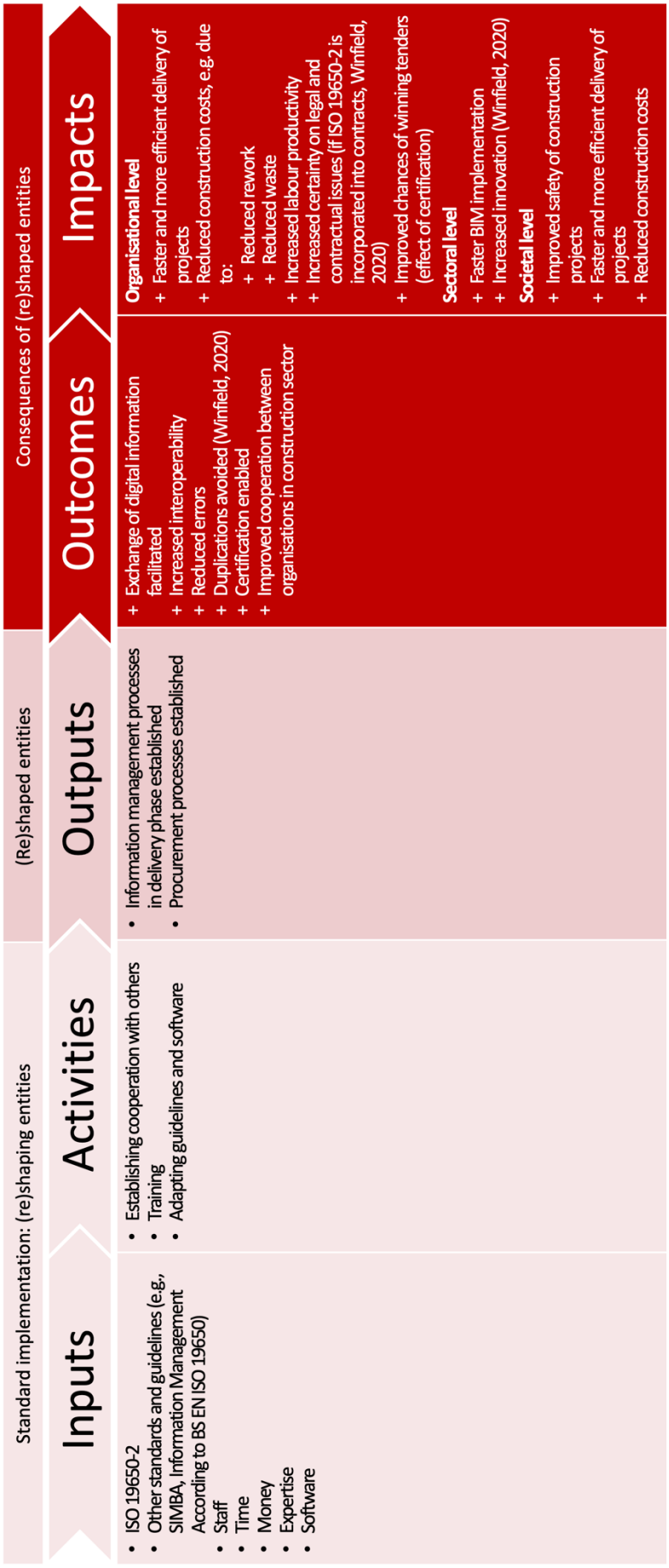

Figure 23: Hypothetical logic model of ISO 19650-2's impacts (building information management)

6.8.4 Discussion: impacts of ISO 19650-2

ISO 19650-2 is gradually being implemented in the construction sector in Norway, but not consistently, and currently still at small scale. Its impact in Norway is thus very small, even though the predecessor standard PAS 1192-2 has been estimated to save up to 22% in construction costs (Naden, 2019). In general, BIM has benefits, such as cost reduction and control through the life cycle of construction projects, time saving, and enhanced communication (Bryde et al., 2013).

Our interviews suggest that inconsistencies in implementation relate to issues at software developers and in the SIMBA guides, which cause different suppliers' software not being interoperable. Construction companies are therefore likely to need adapting their processes in each project to interoperate with their partners. However, our interviews also suggest that the standard already helps define responsibilities, authorities, and tasks related to BIM, and thus facilitates cooperation.

ISO 19650-2's adoption is also hampered by the need for national adaptation, because relevant procurement regulation differs per country (Popov et al., 2021). ISO 19650-2 encourages national standards bodies to document information relevant to specific countries in national annexes. Few countries (e.g., the UK, see Winfield, 2020) have done so. Therefore, developing national guidelines may be necessary for the standard to reach its potential impact. Indeed, guidelines have been developed in Norway. Many companies use SIMBA instead of ISO 19650-2, which includes elements of the ISO standard in its most recent version. Furthermore, the standard is part of education at Norwegian universities. Some Practices from the standard may thus be followed in Norway, even if it is not fully implemented.

The UK situation gives an indication of ISO 19650-2's potential impact. The UK government mandated BIM for centrally procured construction projects in 2016. Fully collaborative BIM was developed to meet this mandate (Infrastructure and Projects Authority, 2016). PAS 1192 suites that set requirements for collaborative production of information were published in preparation for the government mandate on BIM implementation (Ajayi et al., 2021). The government mandate and the standards supporting it contributed to increasing BIM implementation in the UK, which reduced construction costs. This shows an impact of the predecessor of ISO 19650-2. Impacts of the ISO standard and how it is implemented in countries other than the UK are not known yet.

6.8.5 Conclusions: relating ISO 19650-2 to the SDGs

Due to its very limited implementation, ISO 19650-2 has no tangible impact yet. The implementations that already can be observed do not meet the standards requirements completely. If the standard reaches more widespread implementation, its *primary impact* can be expected to related to SDGs 9 (*"Industry, Innovation and Infrastructure"*) and 11 (*"Sustainable Cities and Communities"*). By improving collaboration in construction and saving costs, it may also have a *secondary impact* on SDG 8 (*"Decent Work and Economic Growth"*). This improved collaboration may also contribute to reducing waste in construction processes, adding a potential *secondary impact* on SDG 12 (*"Responsible Production and Consumption"*).

7 In-depth case studies: cross-case analysis

In this chapter, we derive general lessons learned from our results from the eight in-depth case studies presented in Chapter 6. These cases were chosen in consultation with the XXM Partners (see Section 2.2.2), and reflect their importance for them. Our results stem from a total of 86 in-depth interviews with experts on the various standards, relevant documents, and further sources. In each case, we applied the logic-model-based approach developed in Section 3.4 to identify impacts and their antecedents. This makes all eight cases comparable, thus providing an excellent foundation for a cross-case analysis. Nevertheless, our work is based on a limited number of cases, which may not be representative for the entire body of standards. Further work is needed to confirm these findings.

Our analysis starts by highlighting how standards' ability to generate impact depend on the ecosystems around them (Section 7.1). Section 7.2 discusses in more detail how the observed impacts can be understood: it classifies them, and shows recurring elements. Section 7.3 concludes by relating the observed societal impacts to the SDGs. Table 10 on p. 85 provides an overview over key characteristics of the investigated standards.

7.1 Standards' ecosystems: relations with impacts

Our analysis shows that each standard is part of a broader ecosystem.[56] Standards and these ecosystems evolve in parallel. New standards are developed because stakeholders see a market need, possibly triggered by elements of the context. This is reflected in a standard's New Work Item Proposal (NWIP), and underlies the committee's work. Subsequently, standards are made available to the market. Our research focusses on what happens from this point onwards. Whether and how a standard is implemented also is affected by its ecosystem. In return, standards generate impact by triggering changes in this environment.

We find that there are at least nine relevant aspects of a standard's relations with its context: (1) motivations behind standard implementation, (2) regulation and policy, (3) certification schemes, (4) national characteristics, (5) relationships with other standards, (6) organisational context of implementation, (7) specificity of a standard's requirements, (8) clarity of the standard document, and (9) completeness of a standard's implementation. Points (1) to (6) relate to how well the ecosystem facilitates the standard, Points (7) and (8) relate to how well the standard is adapted to its ecosystem's needs, and Point (9) results from a (mis)match between these factors.

Below, we explain these factors, Table 10 on p.85 summarises them for our cases.

1. Various *motivations may be behind organisations implementing standards*.[57] Possible motivations include, e.g., market demands from customers, broader societal expectations (not only from customers) about sustainability, improving organisations' operations-effectiveness, or responding to legal mandates. Depending on the specific

[56] Based on Bogers et al. (2019), we define an ecosystem as an interdependent network of actors jointly creating value. In many ecosystems, standards have an important function for this joint value creation, e.g., by coordinating these actors' activities.

[57] Similar demands may already underlie a standard's development. This is out of scope for our analysis.

motivation for using a standard, this may lead to profound changes, or to "window-dressing". In some cases, stakeholders may also perceive no need for the standard, even if one was identified in the NWIP.

2. Standards may correspond to *regulatory requirements and/or government policy*. In such instances, implementing the standard supports organisations in complying with these requirements. This enhances a standard's societal-level impacts, as it helps achieve the targets underlying the regulation. In many such cases, *CE-marking* is relevant, very often in a safety context.
3. Standards may underlie *certification schemes*, where third parties assess whether a standard has been successfully implemented. Certification supports communication to external parties. This signalling effect may help create additional awareness, leading to business benefits for producers and supporting consumers in making more informed choices. Over time, this may shift markets' and society's expectations, to the extent that organisations, products, or services are only competitive if they are certified.
4. *National characteristics* may relate to all aspects listed above, but also factors like the local climate. Such characteristics may make a standard effective in some countries, but not in others.
5. *Relationships with other standards* may be competing and/or complementary:
    a. *Competing standards*, which offer alternative solutions to the same problem, may cause confusion about which standard to adopt. It may also lead to inconsistencies, which can, e.g., hamper cooperation between organisations.
    b. *Complementary standards* may need to be implemented alongside each other to reach their full potential. In such cases, it is difficult to disentangle one standard's impacts from those of the others. Often, complementary standards are part of the same standard family, but they may also come from other sources.
    c. There may also be *discrepancies* between contents of standards that might otherwise be complementary, leading to further issues with implementation.
6. The *organisational context of implementation* also affects standards' impacts. We observed that standards may, e.g., require substantial expertise to implement and/or rely on the presence of certain management systems and processes. Such standards may be effective when implemented in large organisations with many resources, but less effective at SMEs.
7. There may be *ambiguous requirements or several options for solving a certain problem in the standard* where stakeholders expect specific instructions. This may even be intended by the standard's authors when requirements are phrased in a manner that leaves room for different implementations. For example, we found that ISO 14064-1 (GHG emissions) and ISO 14044 (LCA) do not specify which measurement methods should be used and permit selective reporting. In the worst case, this may lead to the standard having negative impact. In the ISO 14064-1 (GHG emissions) and ISO 14044 (LCA) cases, this may, e.g., give rise to greenwashing.
8. The *standard document may lack clarity*. These issues may include wrong and/or ambiguous translations (ISO 27001 in Denmark), absent standard translations into

the national language (most standards), or standards which are not written in an accessible manner (ISO 27001; ISO 22397; ISO 14064-1 in comparison to the more user-friendly text of the GHG Protocol).

9. *Completeness of a standard's implementation* affects how it can contribute to its ecosystem. In particular, mismatches between standards and their ecosystems may result in the standard being partially implemented. While complete implementation is no guarantee for positive impacts, our analysis shows that partial implementation may often drive unintended outcomes. For example, in the case of ISO 19650-2 (building information management) this is likely to hinder cooperation between organisations with inconsistent implementations of the standard, once it is used more broadly.

All of this means that a standard's impact cannot be assessed in isolation. Any attempt to understand its impact must rather place the standard in its broader environment, and study this entire ecosystem. Our results show that this may reveal different degrees of interdependence, which affect possible pathways for impact (see Table 10 on p.85, numbers in the table indicate the factors explained above). On one end of such a scale, EN 16516 (emissions of construction products) is embedded in a relatively simple ecosystem with few other factors (most importantly, the M1 classification scheme), where it fulfils a clearly defined role. This ecosystem serves a clear demand in the market (cleaner indoor air), making its positive societal impact evident. On the other end of such a scale, standards like ISO 14064-1 (GHG emissions) and ISO 14044 (life cycle assessment) are embedded in very complex ecosystems, where they interrelate with many factors, and may even be subject to abuse for greenwashing.[58] In these cases, the eventual impact depends on how well the 'building blocks' of these ecosystems are aligned.

[58] Table 11 in Section 7.3 also reveals that these standards affect a broader range of SDGs.

Table 10: Comparison between investigated standards

	ISO 14155: Clinical trials	ISO 14064-1: GHG emissions	ISO/IEC 27001: Information security management	EN 16516: Emissions of construction products	ISO 17088: Compostable plastics	ISO 14044: Life cycle assessment	ISO 22397: Societal security	ISO 19650-2: Building information management
Key motivation(s) for standard implementation (1)	Conducting safe and ethical clinical trials Meeting legal requirements	Meeting demands for accountability regarding environmental impact *Potential, but not observed:* greenwashing	Protecting digital assets against cyberthreats Meeting legal requirements	Demonstrating product safety Obtaining certification	Limited implementation in Sweden	Support for obtaining Environmental Product Declarations (EPDs)	None	Increasing awareness of BIM's benefits, as reflected in demands by Norwegian Directorate of Public Construction and Property (Statsbygg)
Stakeholders' perception of need	High	Moderate NWIP identified need for new standard despite similar GHG Protocol standard already being available	Moderate	High	Limited	Limited, mainly driven by demand for EPDs	None NWIP identified need for new standard despite potential users perceiving no problems with existing approaches	Limited Other guidelines are available (see below)
Links to regulation and/or policy (2)	To be harmonised under EU Medical Device Regulation (MDR)	Relevant for Kyoto Protocol & EU Emissions Trading Scheme (ETS)	Danish National Strategy for Cyber and Information Security	Listed as 'horizontal specification' under Construction Product Regulation (CPR)	No direct links, relevant for EU Packaging and Packaging Waste Directives, and for European Plastics Strategy	Relevant for European Commission's Integrated Product Policy & International Life Cycle Data System (ILCD)	None	None

	ISO 14155: Clinical trials	ISO 14064-1: GHG emissions	ISO/IEC 27001: Information security management	EN 16516: Emissions of construction products	ISO 17088: Compostable plastics	ISO 14044: Life cycle assessment	ISO 22397: Societal security	ISO 19650-2: Building information management
CE-marking (2)	Yes	No	No, may become an option	No, may become an option	No	No	No	No
Links to certification schemes (3)	Yes	'Verification' of emissions resembles certification	Yes	Yes, standard supports Finnish M1 Classification	Yes	Yes, building certification schemes (e.g., LEED, BREEAM, DGNB) & standard underlies Environmental Product Declarations (EPDs)	No	Yes
Relevant national characteristics (4)	Finnish law (MDA) supports the MDR	Swedish Environmental Protection Agency considers other standards as more relevant for ETS	All Danish government agencies are required to implement standard	High share of time spent indoors and frequent use of wood-based construction materials → high demand for low-emission construction products	Low temperatures in Sweden make composting infeasible	Construction sector accounts for largest share of standard's buyers, driven by high demands of EPDs	N/A	Norwegian BIM guidelines developed by Statsbygg (SIMBA) are used by many companies

	ISO 14155: Clinical trials	ISO 14064-1: GHG emissions	ISO/IEC 27001: Information security management	EN 16516: Emissions of construction products	ISO 17088: Compostable plastics	ISO 14044: Life cycle assessment	ISO 22397: Societal security	ISO 19650-2: Building information management
Relationships with other standards (5)				N/A				
Competing (5a)		Other standards provide similar requirements for sites instead of entire organisations; GHG Protocol is available for free and preferred by many parties	NIST 800-53 and standards published by Center for Internet Security (CIS)		EN 13434, EN 14995, ASTM D6400, AS 4736, CAN/BNQ 0017-088		Other standards for societal security	
Complementary (5b)	European Commission Guidelines on Good Clinical Practice, FDA Guidance	ISO 14060 family of standards	National guides for SMEs		ISO 18606 and other ISO standards on test methods	Other standards for LCA and EPDs (e.g., ISO 14025, ISO 21930, EN 15804, EN 15978)	ISO 22300 is complementary, but standard can also be used alone	ISO 19650 family and other BIM standards
Discrepancies (5c)	ISO 14971 (risk management of medical devices)				Discrepancies occur between ISO and EN standards		Discrepancies with other standards for societal security	

	ISO 14155: Clinical trials	ISO 14064-1: GHG emissions	ISO/IEC 27001: Information security management	EN 16516: Emissions of construction products	ISO 17088: Compostable plastics	ISO 14044: Life cycle assessment	ISO 22397: Societal security	ISO 19650-2: Building information management
Organisational context of implementation (6)	SMEs may not have required expertise for implementation in-house	Consultants often used instead of in-house experts; information from environmental or quality management systems needed	Difficult to implement for SMEs, experience with other management system standards (e.g., ISO 9001) helps	N/A	Expertise available in organisations that carry out tests (e.g., RISE research institute)	Consultants and/or research institutes often used for conducting LCA	Partnership building practices without using the standard are prevalent	Companies rely on other guidelines
Fit of standard document to context (7/8)	Requirements leave a degree of freedom on how to complete clinical trials, this is appreciated by the field	Requirements leave more freedom to implementors than desired; GHG Protocol is more user-friendly	Translation issues, 'Harmonised Structure' for management systems makes parts of standard complex to read and more abstract	Standard meets requirements of field	Issues in fit to national characteristics (see above); low consumer awareness may lead to waste disposal which is not aligned to the standard	Requirements leave room for methodological choices	Complex to read	Issues related to national characteristics and organisational context (see above) suggest that there are issues with fit to context
Cases of incomplete implementation (9)	No	Potential, but not observed; incomplete implementations may be used for greenwashing	Yes	No	No	Potential, but not observed	No	Yes (by software firms and governmental construction agencies)

7.2 Understanding impacts: classification and recurring elements in logic models

We identified a case-specific logic model for each standard that we studied, based on the approach which we developed in Section 3.4. Using these logic models, we were able to understand how the respective standard and other elements of its ecosystem cause impacts. These impacts can be classified along the following dimensions, which are useful for a better understanding of how standards affect society:

- *Primary vs. secondary impacts:* As outlined in the case descriptions in Chapter 6, each standard was developed to address a particular challenge. Its primary impacts relate to how successful its contribution to resolving this challenge is. In particular the two cases from Finland (ISO 14155, clinical trials for medical devices; EN 16516, emissions of construction products) score well on this dimension. A standard's secondary impacts relate to any effects beyond the core challenge that it aims to address. Often, secondary impacts may be unintended.
- *Directionality of impacts:* Impacts may be positive, neutral, or even negative. This depends both on the contents of the standard and its ecosystem (see Section 7.1).
- *Level of impacts:* We observe impacts of standards on organisational level, within a specific sector, or in society as a whole.
- *Magnitude of impacts:* Especially if standards are not used at all (ISO 22397, societal security) or implemented at small scale (e.g., ISO 17088, compostable plastics; ISO 19650-2, building information management), their impacts are non-existent or negligible. On the other hand, standards implemented by many parties in their target groups (again ISO 14155, EN 16516) and/or the most important parties (e.g., ISO 27001, information security management) contribute to substantial change at societal level. Future research may attempt to quantify this impact, but this was out-of-scope for our project.

Each logic model is case specific, but we see recurring factors in multiple cases. Figure 24 on p.90 gives an overview over these recurring factors. They can provide some guidance on where to focus investigations of other standards. Further research is also needed to determine how generalisable these recurring factors are. We derived them from studies of eight standards, which are not representative for the entire body of standards.

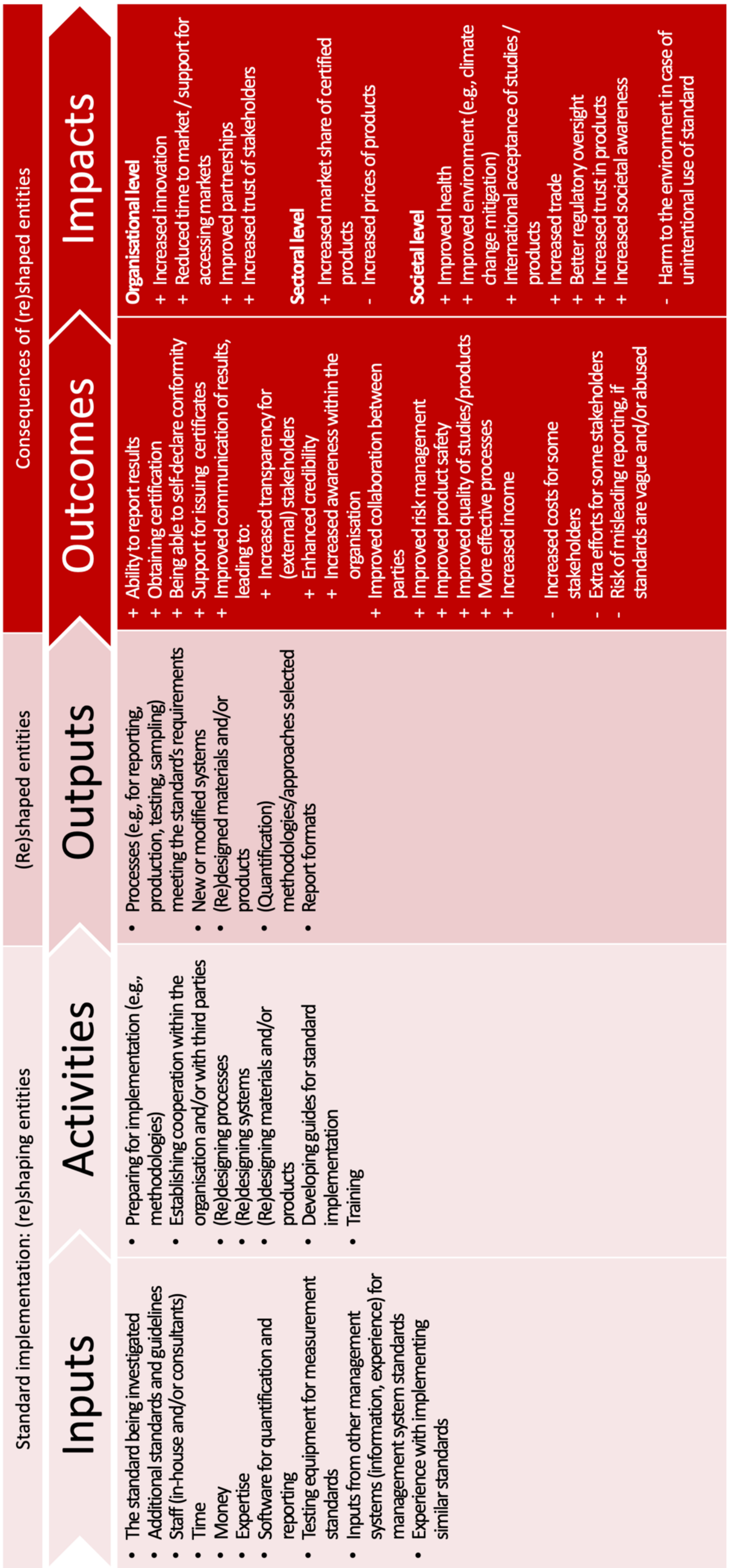

Figure 24: Common elements in logic models

7.3 Relating societal impact to SDGs

As a widely used approach to classifying societal impacts, the SDGs provide a helpful framework for comparing the specific impacts of varied standards. Table 11 provides an overview over the impacted SDGs identified in the case studies in Chapter 6. In this table, the letter P identifies primary impacts, whereas secondary impacts are marked with S. Capital letters denote observed impacts, lowercase letters denote potential impacts. Underlined letters refer to what affected SDGs already identified by ISO on its website.

Table 11: Overview of observed impacts on SDGs

Standard	SDGs+																	Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	C.P.	
ISO 14155: Clinical trials			P						S							S			3
ISO 14064-1: GHG emissions[59]									s		s	s	p	s	s				6
ISO/IEC 27001: Information security management			S	S		S	S		P		S					S			7
EN 16516: Emissions of construction products			P						S			S							3
ISO 17088: Compostable plastics[60]						s						p	s	s	s				5
ISO 14044: Life cycle assessment[61]									s		p	p	p	p	p				6
ISO 22397: Societal security[62]			p								p						p		3
ISO 19650-2: Building information management[63]								s	p		p	s							4

[59] The standard can contribute to these SDGs if used as intended. Misuse may lead to negative effects on these SDGs.

[60] The standard can contribute to these SDGs if it is implemented at a larger scale than currently. Positive effects also depend on whether compostable plastics are the preferred solution for the specific situation. If implemented in a non-optimal manner, the standard may affect these SDGs negatively.

[61] The identified effects on SDGs result from the system of standards and Environmental Product Declarations (EPDs), not the standard alone.

[62] The standard is currently not implemented. It may affect these SDGs, if it is used as intended.

[63] The standard may contribute to these SDGs if more widely implemented.

When comparing these impacts with the potential impacts identified in our pre-study (Table 8 on p.37), we notice a comparable number of impacted SDG per standard.[64] We took a deliberately 'liberal' approach in the pre-study, with low thresholds for relating a standard to a particular SDG. Our in-depth cases suggest that this broad potential for standards' impacts still holds when considering more extensive evidence than we did in the pre-study. In all cases where ISO has related the studied standards to the SDGs, we also find broader (potential) impact than ISO did in its previous effort.

However, we only mostly identified *potential* impacts of standards on the SDGs. Due to the factors discussed in Sections 7.1 and 7.2, most standards considered in this project cause *few actual changes* for society. Furthermore, in some cases standards may also hinder progress on the SDGs, rather than support it (e.g., if standards for environmental purposes – GHG emissions and LCA – are abused for greenwashing). Our study therefore shows (potential) benefits of standards for the SDGs, but also highlights risks that need to be addressed.

[64] 198 affected SDGs across 48 standards = 4.125 SDGs per standard in the pre-study. 37 affected SDGs across 8 standards = 4.625 affected SDGs per standard in the in-depth studies. Due to the low number of standards in the in-depth study, these numbers may not be representative, and need to be confirmed in future studies.

8 Applied methodology for measuring impacts

For our study, we conducted eight detailed studies of standards' impacts. Based on our review of alternative approaches (Chapter 3) and our results, we recommend an applied methodology for future studies of the topic. The methodology is based on a six-step process (Figure 25),[65] and a number of frameworks/tools, which have proven to be essential for the analysis in our study and can support future studies on the topic.

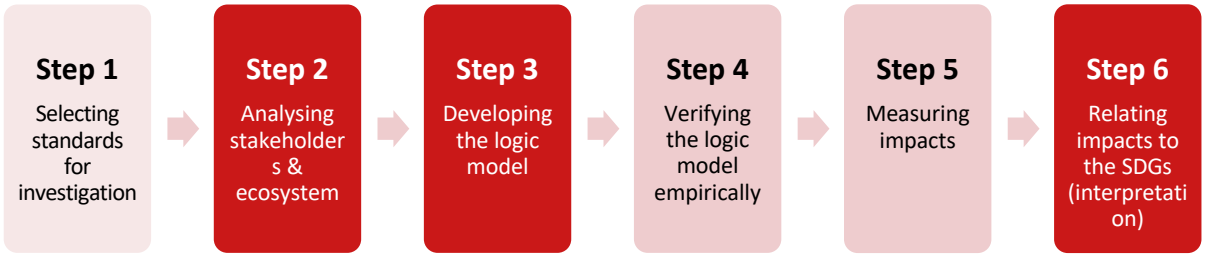

Figure 25: Steps of impact conceptualisation and measurement

Section 8.1 explains the reasoning underlying this process, and how these tools and frameworks are incorporated into our process for assessing standards' societal impacts. Sections 8.2 to 8.7 offer a step-by-step guide for readers, who are applying our methodology.

8.1 Reasoning underlying the applied methodology

In our work to study standards' societal impacts, we encountered two challenges: (1) understanding how a specific standard impacts society, and (2) finding evidence of changes that eventually lead to impact. Our recommended process for impact measurement (Figure 25 on p.93) addresses each challenge in distinct steps: Steps 1, 2, and 5 aim to resolve the first challenge, whereas Steps 3 and 4 address the latter.

This gives readers, who want to study standards' impacts, two options (see Table 12 on p.94): (1) Focussing on *understanding* potential impacts (mostly based on desk research), thus skipping Steps 3 and 4, or (2) Focussing on empirically *measuring* impacts, following all steps of our methodology.

8.1.1 Frameworks/tools underlying the applied methodology

In both options for studying impact, four frameworks/tools underlie our recommended approach to addressing the challenge of understanding impact:

1. Stakeholder analysis (recommended by academic impact-assessment literature and applied to the standards context, underlying Step 2),
2. A checklist for analysing a standard's ecosystem and its context (based on our findings in Section 7.1, underlying Step 2),
3. The logic model for standards (developed in Section 3.4, underlying Step 3),
4. The SDGs as a framework for classifying impacts (underlying Step 6).

[65] In practice, this is an iterative process. We portray this as a linear process for reasons of simplicity.

In the remainder of this chapter, we provide a step-by-step guide to applying the recommended process.

Table 12: Options for studying standards' impacts

	Focus on *understanding* potential impact	Focus on empirically *measuring* impact
Aim	• Predicting results of implementing a standard	• Finding empirical evidence of actual impacts
Result	• Potential societal impacts	• Potential and actual societal impacts
What to do	• Apply the frameworks/tools underlying our methodology	• Apply the frameworks/tools • Test the logic model based on qualitative data • Measure impact using quantitative indicators
Strengths	• Ease of use • Supports communicating standards' (expected) benefits	• Comprehensive measurement, based on evidence
Limitations	• Unable to distinguish between actual and potential impacts	• Time consuming • Required data may not be available
Excluded steps (Figure 25 on p.93)	• Steps 4&5	• None

8.2 Step 1: Selecting standards for investigation

General considerations in selecting standards for an impact study include (1) the a-priori expected impact, and (2) the ability to measure it. Both depend on the standard's use (i.e., number and scale of implementations, and use by notable stakeholders), for which sales figures may be a proxy. Furthermore, practical considerations related to data availability and access may be relevant. Unless a study is motivated by interest in a specific standard, appropriate selection criteria depend on the study's purpose:

- *Identifying a collection of standards' 'average' impact* (e.g., across all standards in a specific technical field): select a random sample, which may include standards with few or no sales.
- *Identifying the sum of impacts of a collection of standards*: select standards with more expected impact. See Chapter 2.2.1 for an example of selecting 48 standards based on sales figures.
- *Exploring impacts across a variety of standards*: select cases to maximise diversity across this variety. See Chapter 2.2.2 for an example of selecting eight cases relying on several criteria.

8.3 Step 2: Analysing the standard's stakeholders and ecosystem

Previous research on impact measurement highlights the importance of embedding a stakeholder analysis in developing theories of change and repeating it over time

(Hehenberger et al., 2015; Picón Martínez et al., 2021). In the standards context, our research adds the importance of understanding further factors in the standard's ecosystem.

8.3.1 Stakeholder analysis

Stakeholders may be identified using ISO's pre-defined stakeholder categories ISO (2019b) (see text below), or more detailed approaches (e.g. de Vries et al., 2003).[66] The first approach is easier to apply, whereas the latter is likely to generate more accurate results.

ISO's (2019b) pre-defined categories of stakeholders are likely to be relevant for most standards, but may omit more context-specific stakeholders for certain standards. The stakeholder categories are as follows:

- Industry and commerce (e.g., manufacturers, producers, service industries, banks and financial institutions; business and trade associations)
- Government
- Consumers
- Labour (e.g., trade unions and federations of them)
- Academic and research bodies
- Standards application (e.g., testing, certification and accreditation bodies)
- Non-governmental organisations (NGO)

In line with existing best-practice (Hehenberger et al., 2015; Picón Martínez et al., 2021), the analysis may focus on the most affected and/or important stakeholders. These stakeholders should be representative for the interests surrounding the standard.

8.3.2 Analysing the standard's ecosystem

Researchers should also scan the standard's ecosystem. As our in-depth case studies (Chapter 6) show, standards' impacts are heavily influenced by contextual factors, such as legislation and regulation, competing or complementary standards, and national particularities (e.g., the climate in the ISO 17088 compostable-plastics case). Users of our methodology should use the factors detailed in Table 10 on p.85 as a 'checklist':

- Key motivation(s) for standard implementation,
- Links to regulation and/or policy (including whether the standard can be used for CE-marking),
- Links to certification schemes,
- Relevant national characteristics,
- Relationships with other standards (which may be competing, complementary, and/or exhibit discrepancies),
- Organisational context of implementation,
- Specificity of requirements in the standard,
- Fit of the standard document to its context,
- Cases of incomplete implementation.

[66] See Appendix 11.7 for an overview of the main steps of de Vries et al.'s (2003) detailed method.

8.4 Step 3: Developing the logic model

A specific logic model for the investigated standard identifies potential impacts and how they emerge. It serves as a basis for collecting and analysing empirical data in a structured manner, as described in Steps 4 and 5.

This section gives instructions on how to apply the logic model for the selected standards, based on our work in Section 3.4. Deriving the logic model may be based on (1) information from the standard document and the researcher's expertise, and/or (2) also additional sources. The recurring elements of the logic model identified in our analysis (Figure 24 on p.90) provide a starting point for this. The case-specific logic models in Chapter 6 show what the end-result may look like.

8.4.1 Deriving the logic model from the standard document

The primary source for developing the logic model is the standard document. Outputs in the logic model can be derived from what is prescribed in the standard.[67] This may cover, e.g., reporting formats, characteristics of management systems and their elements, performance requirements and testing procedures, or process characteristics, which are assumed to be in place after standard implementation.

The logic model can subsequently be elaborated iteratively by considering (1) necessary inputs and activities for obtaining these outputs, and (2) likely outcomes and impacts resulting from them. Inputs and activities identified as necessary may also give grounds for anticipating unintended results.

8.4.2 Identifying expected results from additional sources

In addition to the standard, secondary sources, scientific literature, and informal input from stakeholders can be used to identify additional expected results. This may also provide initial evidence to confirm or contradict the expected outcomes and impacts and thus show *actual* results.

Secondary sources

Secondary sources provide insights into what is already known about a standard. Relevant sources may include, e.g., news articles, opinion papers, and statistics about the prevalence of certification.

Scientific literature

Impacts of some widely-adopted standards (e.g., ISO 9001, ISO 14001, ISO/IEC 27001) have been studied. This evidence can be used in deriving a logic model. Appendix 11.5 provides an example of how scientific literature can be identified, based on our approach for reviewing literature in Chapter 4.

Consulting stakeholders

Informal discussions with experts on the standard may offer further input for the logic model. More formal and extensive interviews with stakeholders may be used as part of Step 4 (Section 8.5).

[67] This can often be derived from a standard document's table of contents, introduction, and scope. Reviewing the document's entire technical content may lead to a more accurate estimation.

8.5 Step 4: Verifying the logic model empirically

When entering Step 4, researchers need to determine their study's scope (organisational, national, or global).[68]

In-depth interviews with experts are likely to be the primary source of data at this stage. Suitable experts (1) have first-hand experience of implementing the standard and/or (2) are generally familiar with the technical field. Interviews should aim to both (1) discover new elements of the logic model, and (2) verify elements already included. Questionnaires may also be used at this stage.[69]

The collected evidence ideally covers situations before and after implementation, and/or compares organisations which have implemented the standard with those that have not. This verifies the logic model with empirical evidence, and provides further information about the relations between the ecosystem and the standard. However, it is challenging to determine whether the observed outcomes and impacts can really be attributed to the standard's implementation or also depend on contextual factors. Following this analysis, the logic model can be revised to provide a foundation for measuring impacts quantitatively (Step 5).

8.6 Step 5: Measuring impacts quantitatively

The logic model provides focus to quantitatively measuring impacts by indicating what needs to be measured. This step was intended to be part of our in-depth case studies, but none of the distributed questionnaires generated enough responses. Measuring impacts quantitatively is therefore challenging, but we present some pointers on how it may be conducted if included in a project's scope.

As much as possible, measurement should be based on accepted indicators. Potential sources of such accepted indicators include, e.g., the Global Reporting Initiative's standards (GRI, 2022b), the indicators used in the Sustainable Development Report (Sachs et al., 2021) and the United Nations Development Programme's SDG Impact Standards (UNDP, 2021). Appendix 11.8 provides an overview over these and some additional frequently used sets of indicators. However, such indicators may not always capture a standard's specific characteristics. Quantitative measurement may need to focus on capturing outcomes or outputs as a proxy for impacts, which may be too long-term for measurement. Clifford et al. (2014) and Hehenberger et al. (2015) provide further guidance on quantitatively measuring impacts.

8.7 Step 6: Relating impacts to the SDGs (interpretation)

The SDGs are arguably the most common way of capturing dimensions of societal impact (see Chapter 3.2). They help make standard-specific effects and impacts comparable.

[68] Reliably measuring impacts on a global level is very resource-intensive.

[69] The experience in our in-depth case studies (Chapter 6) suggests that getting sufficient responses from such questionnaires may often be challenging. Questionnaires are therefore only a suitable data source if a high response rate can be ensured.

For example, our analysis of ISO 27001 (information security management, Section 6.3) reveals that the standard contributes to data protection, whereas an analysis of ISO 14155 (clinical trials for medical devices, Section 6.1) shows that the standard helps serve unmet healthcare needs. To support comparison across standards, identified impacts can be grouped and classified according to which SDG(s) they affect.

Subsequently, the overall effect of a standard per SDG can be recorded in line with the dimensions, which we identified based on our analysis in Section 7.2. This includes whether impacts (1) are primary or secondary, (2) are “positive”, “negative”, “neutral”, or “mixed” (in case there are both positive and negative individual effects on one SDG, or different stakeholders are affected positively/negatively), (3) which level they concern, and (4) their magnitude.

9 Conclusions & recommendations

In our project, we combined insights from academic literature, a pre-study of 48 standards, and eight in-depth case studies. Based on these insights, we provide clear evidence about standards' effects on society, and what causes these effects. In doing so, we reached five goals, that were defined in the agreed project proposal (Version 2021-06-14):[70]

1. Provide an overview of dimensions of societal impact of standards;
2. Provide an overview of scientific literature on impacts of standards;
3. Develop cases that provide evidence of societal impacts of standards;
4. Develop a methodology to demonstrate the societal impacts of standards;
5. Propose how the methodology/test results can be transferred to regular use by the funding NSBs.

In the subsequent parts of this chapter, we show how our project delivers on each of these goals. In line with Goal 5, Section 9.5 focusses on recommendations for the XXM Partners and other standard bodies.

9.1 Goal 1: Overview over dimensions of standards' impacts

Societal impact has many dimensions, which may relate to, e.g., public health, education, or the environment. Our literature review (Chapter 3) identified the 17 United Nations Sustainable Development Goals (SDGs) as the most suitable framework for classifying impacts and making them comparable across the board. The SDGs represent a global consensus on which areas societal development should focus. They cover diverse areas, such as "Good Health and Wellbeing" (SDG 3); "Affordable and Clean Energy" (SDG 7); "Industry, Innovation and Infrastructure" (SDG 9); and "Responsible Consumption and Production" (SDG 12). As an (almost) universally known framework, they are suitable for communicating the impacts of standards to a large audience.

Our pre-study (Chapter 5) identifies potential societal effects of standards. We selected 48 standards mainly based on their sales numbers and an aim to cover the breadth of technical topics. While this may bias the study towards more impactful standards, it does show the whole range of standards' potential impacts. These impacts may affect all SDGs and/or relate to consumer protection aspects not already covered by the SDGs. For many assessed standards, the pre-study also identifies multiple affected SDGs. In many cases, such effects may even go beyond the standards' intentions. This breadth of impacts is also confirmed in our in-depth case studies (Chapter 6).

9.2 Goal 2: Overview over scientific literature on standards' impacts

Standards' importance for society has been widely recognised. This results from standardisation processes, where a range of stakeholders contribute their knowledge to jointly solving challenging technical and societal issues. Standards make the resulting consensus available to broad audiences, thereby guiding society on challenges it faces. While this view on standards is widespread in academic literature, there is relatively little research

[70] The deliverables related to these goals from the agreed project proposal are included in Appendix 11.2.

on their societal impacts as such. The limited available research focusses on specific widely-used standards (ISO 9001 and ISO 14001). Our review of this work (Chapter 4) shows that mainly economic/business impacts are studied for ISO 9001 (quality management systems) with some evidence of it also impacting SDGs being present. For ISO 14001 (environmental management systems) our review finds that there is substantial evidence about environmental and economic/business impacts, with some studies suggesting wider societal benefits. As many studies suffer from biases, the real benefits are likely to be less than suggested. They depend on how well ISO 9001- or ISO 14001-based management systems actually function.

Given the scarce work about standards' societal impacts, our review covers other areas of research (Chapter 3). Societal impact measurement is an active field of research with a multitude of approaches. In particular the literature streams on social enterprises (SEs) and societal impact assessment (SIA) have been long established. They offer insights that can be transferred to the standards context.

We identified the Logic Model as a suitable basis for next steps of our project. This model is central to much of the scientific literature on impact measurement and enjoys broad academic recognition. We adapted this model to the standards context (see Figure 3 on p.26). The adapted model helps identifying which impacts a standard can generate, also taking into account the ecosystem around it, in a structured manner. It is therefore at the core of our empirical work (see Sections 9.3 and 9.4 below).

9.3 Goal 3: Evidence of standards' societal impacts – empirical research

At the core of our project lie eight in-depth case studies of standards' societal impacts. Each study focusses on one specific standard's impacts, and was carried out by a master student during an internship at one of the XXM Partners (see Chapter 6). Standards were selected in consultation with the XXM Partners, and reflect topics of importance for them. The selected standards cover a broad range, e.g., greenhouse gas (GHG) emissions reporting (ISO 14064-1), clinical trials for medical devices (ISO 14155), information security management (ISO/IEC 27001). Overall, our insights are based on 86 in-depth interviews with experts on the researched standards, relevant documents, and further sources.

Our findings show that standards' impacts are closely related to their implementation. Some investigated standards are not implemented at all (ISO 22397, societal security), or only on a small scale (ISO/IEC 27001, information security management; ISO 17088, compostable plastics; ISO 19650-2, building information management). This leads to very limited impact, unless the implementing organisations are major actors in the market (as observed in the ISO/IEC 27001 case). Thus we mostly identified potential impacts, which may be achieved if these standards are implemented on a larger scale. Out of the investigated standards, the most positive and most tangible impacts are created by ISO 14155 (clinical trials for medical devices) and EN 16516 (emissions of construction products).

A key result concerns the importance of a standard's ecosystem. All investigated standards are deeply embedded in ecosystems. Their (mis)alignment with other elements of this

context drives their impact to such an extent that it is difficult to isolate the standard's impact from that of the ecosystem as a whole.

For example, the positive impact of EN 16516 (emissions of construction products) is made possible by its links to the Finnish M1 classification scheme for building products. A negative example can be found in the case of ISO 14064-1 (GHG emission reporting). This standard is misaligned with other elements of its ecosystem, e.g., because its requirements are not as clear as expected by stakeholders, and many stakeholders do not understand the standard's added value due to overlap with the GHG Protocol standard. This causes it to have limited impact. In the worst case, this may even lead to it being abused for greenwashing, although we found no evidence of this actually happening in Sweden (where we conducted this case study).

Chapter 7 draws general conclusions from the insights from all eight cases. Our analysis identifies a number of factors (e.g., motivations behind standard implementation, competing and/or complementary standards, links to regulatory requirements, characteristics of the standard itself), which contribute to a standard's positive and/or negative impact. This analysis also identifies recurring elements in the causal chains leading to impact across the eight cases, and the observed impacts on the SDGs.

When linking our results to the SDGs, we notice that standards tend to have a number of secondary impacts, which go beyond their purpose. For example, ISO 14155 (clinical trials for medical devices) does not only affect SDG 3 ("Good Health and Wellbeing"), but also SDG 9 ("Industry, Innovation and Infrastructure") and the institutional aspect of SDG 16 ("Peace, Justice and Strong Institutions"). This implies that several standards' effects go beyond the ones already identified by ISO in its own classification of standards according to SDGs (ISO, 2022b). However, many of these links to SDGs remain potential, because of lack of implementation (see above).

9.4 Goal 4: Applied methodology for demonstrating societal impacts

Based on our review of alternative approaches to impact measurement, and our insights from the eight in-depth case studies, we developed and applied a methodology for measuring standard's societal impacts (Chapter 8). This methodology recommends a six-step process, which is based on four frameworks/tools which have been proven essential in our project:

5. Stakeholder analysis,
6. A checklist for analysing a standard's ecosystem (based on our analysis in Chapter 7),
7. The logic model for standards (developed in Chapter 3),
8. The SDGs as a framework for classifying impact.

Our applied methodology can be used for studying further standards' impacts in a systematic manner. The methodology can be used for *understanding* potential impacts, or further for empirically *measuring* impacts.

9.5 Goal 5: Recommendations to National Standard Bodies

Our results have a number of clear implications for the XXM Partners, ISO/IEC, CEN/CENELEC and their members. Below, we provide the recommendations following on from these implications. The XXM Partners' main motivation for commissioning this project was their desire to better be able to communicate standards' societal benefits to policymakers and other stakeholders. Our recommendations in Sections 9.5.1 to 9.5.3 show how our findings can help in doing so. Furthermore, our results give grounds for additional recommendations to the XXM Partners and other standards bodies. Sections 9.5.4 to 9.5.8 detail these recommendations.

9.5.1 Communicate standards' impacts to policymakers

Our results show that there is strong potential for standards having positive societal impacts. This potential is realised when standards are well-aligned with their ecosystems, as we observed in the ISO 14155 (clinical trials for medical devices) and EN 16516 (indoor air emissions) cases. Standards generate this positive impact by providing structured solutions based on standard developers' expertise and stakeholder consensus. When communicating with policymakers, standards bodies should emphasise this strength and standards' functions within their respective ecosystems. They may also emphasise that many (if not most) areas in need of societal change relate to ecosystems, and that standards are often essential for achieving the intended improvements.

Many standards are directly linked to regulation and policy – either directly by being harmonised and providing a presumption of conformity (e.g., expected to be the case soon for ISO 14155), or indirectly by being related to broader policy goals like climate change mitigation. In such cases, communication with policymakers may stress how good alignment between standards, policy priorities, and regulation contributes to overall positive impact on society.

Other standards may achieve positive societal impact without a direct link to regulation and policy. EN 16516 is an example of this. Such cases can be used in communication with policymakers to demonstrate how standards contribute to reaching positive societal change without government intervention.

We also studied a number of standards, which are prevented from reaching their potential positive impact by misalignment with the ecosystem. This misalignment may, e.g., cause insufficient use of the standard. In such cases, standard bodies may still point out the potential positive impacts to policymakers. However, when doing so, they should also communicate how standard bodies intend to achieve better alignment between standards and their ecosystems, e.g., by modifying existing standards, developing new ones, and/or promoting change in other parts of the ecosystem.[71] Finally, standard bodies need to ensure that communication about a particular standard's impacts is coherent with what policymakers hear from other ecosystem parties.[72]

[71] Our recommendations in Sections 9.5.4 to 9.5.7 may support formulating such plans.

[72] This may be supported by addressing societal impact during standard development (see our recommendation in Section 9.5.4),

9.5.2 Communicate standards' impacts to stakeholders, other than policymakers

Communicating to other stakeholders than policymakers, may focus on standards' contributions to achieving the SDGs. Using this widely known framework, NSBs can engage in societal debates to demonstrate standards' value to the public.

Our results show that many standards potentially affect several SDGs, going beyond what was intended by their authors. These effects are also much broader than what ISO already identified in its own classification of standards according to their effects on SDGs (ISO, 2022b). However, NSBs' must also acknowledge that many of these potential effects are not yet achieved. Doing so may even attract new participants to standardisation committees, if this is communicated as an opportunity to improve standards and contribute to positive societal change.

9.5.3 Ensure standards' inclusion in frameworks for measuring societal impact

Policymakers and other stakeholders increasingly demand accountability about societal impacts. This is reflected in an increasing number of frameworks, indicators, and standards for societal impact measurement at the company, sector, and country-levels. A prominent party in this movement is the Global Reporting Initiative, which both develops standards for measuring societal impact in various sectors, and is deeply engaged in the policymaking process (GRI, 2022b, 2022c).

Our results clearly show standards' potential for driving positive change in society. They should therefore be included in societal-impact-measurement frameworks, similar to how standards have been included in the OECD's Oslo Manual for measuring innovation (OECD/Eurostat, 2018). This would not only support clearer communication about standards' societal impact, but also contribute to the measurement frameworks' accuracy.

Further research is needed to develop suitable indicators for this purpose. Nevertheless, we urge standards bodies to already engage in dialogue with the societal-impact measurement community on this topic.

9.5.4 Address societal impacts during the standardisation process, using the Logic Model and other insights from our study

In our in-depth case studies, we found several mismatches between standards and the ecosystems surrounding them, which limited the impact that they have. For example, in at least two cases (ISO 14064-1, GHG emissions; ISO 22397, societal security), the standard's New Work Item Proposal (NWIP) was based on inaccurate information about market needs for a new standard. Our study was scoped to only address the impact of a finished standard (i.e., the result of the standardisation process). However, our results show that this is strongly influenced, if mistakes are made during standard development.

We offer three tools, which may support committees in foreseeing and avoiding such issues at an earlier stage:

1. Our *stakeholder identification method* (see Section 8.3 and Appendix 11.7) can be used to map relevant stakeholders. Particularly relevant stakeholders (in terms of expertise, diversity of stakes, and influence on market acceptance) can be invited to participate in the process.

2. Our *checklist for analysing the standard's ecosystem* (see Section 8.3) may be used during the start-up of a standardisation process to map other elements of the ecosystem, and get a clear view on how the proposed standard may fit into this context.
3. The *Logic Model for standards* (see Sections 3.4 and 8.4) can help anticipate impacts once some information about the standard's requirements is known. This may be integrated in an iterative process of formulating requirements and assessing them using the Logic Model.

9.5.5 Phrase standards in line with their ecosystems' expectations and needs

In several of our cases, the standard's contents did not meet its ecosystem's needs and expectations (see Table 10 on p.85 for details).[73] Based on our data, we identified two issues that should be avoided when developing new standards: (1) unclear language or translations, and (2) excessive flexibility in implementing the standard. The latter affects ISO 14064-1 (GHG emissions) and ISO 14044 (life cycle assessment). While such flexibility may be desirable to some degree, too much of it may give rise to abusing a standard in unintended ways (e.g., in greenwashing context). Furthermore, interviewees questioned the standards' added value due to missing clear instructions. Committees should therefore aim for a good balance between flexibility and clear instructions to avoid such issues.

9.5.6 Take appropriate action regarding standards without implementation

We encountered several standards, which have not or rarely been implemented. Due to this lack of use, these standards can only generate limited impact, if any. Our collaboration with the XXM Partners suggests that standard bodies may not always have accurate information about the actual implementation of their standards. Our results show the importance of such data, which can indicate whether a standard has impact.

Once better data about a standard's use is available, standard bodies may address unused standards in two manners:

1. Generate *publicity for the standard* in question to encourage its use. Our study of ISO 22307 (societal security) shows an extreme case of a standard facing a lack of awareness among stakeholders. Other standards in our study face this problem to a lesser degree.
2. *Withdraw unused standards*. Most standards in our study already underwent one or multiple revisions, including standards facing a lack of use. In cases of limited impact, it may be preferable to withdraw a standard to ensure the continued relevance of the entire body of standards.

9.5.7 Ensure awareness about competing standards within standard bodies and their committees

In some of our case studies, we encountered competing standards, which affected the investigated standard's societal impact. Yet, it did not appear that actors within standard bodies and committees always were aware of this competition. This is, e.g., evident from ISO 14064-1's NWIP, which identified a lack of standards for measuring GHG emissions, despite the very similar GHG Protocol standard already being available in the market. Both our

[73] Implementing Recommendation 9.5.4 may help identify these needs.

findings in this project and other research on standardisation point towards increasing activities of other parties in standardisation (e.g., consortia, NGOs) which may end up competing with standards by ISO, NSBs and other parties in the formal standardisation world. To ensure their continued relevance, standard bodies and committees need to be aware of this competition, and position themselves appropriately in this context.

9.5.8 Need for future research

Our work makes a novel contribution to knowledge about standards' societal impacts. Nevertheless, it is subject to two major limitations: (1) Neither the 48 cases in our pre-study, nor the eight in-depth cases are likely to be representative to the entire body of standards. (2) Despite our efforts to collect data via questionnaires, we have not been able to measure the identified impacts quantitively. These limitations may be addressed in future research, which studies more cases, and gets access to additional data sources.

Our findings also suggest six new areas for research:

1. This project focussed on impact of individual standards. One of our most important findings pointed towards the interdependence with complementary standards, guidelines, and further ecosystem elements for generating impact. Future research may be conducted at the level of standard families, or even entire ecosystems around standards to better grasp these interdependencies.
2. In the long run, it is worthwhile to replicate studies, similar to ours, in a large number of cases at the level of individual standards, standard families, or ecosystems. These cases could be used for developing a large-scale database of standards' impacts. Such a database may provide a representative image of standards' impacts and enable quantitative approaches to studying the phenomenon.
3. We found multiple cases of standards competition. There is already a large body of literature on this topic, but the evidence mostly comes from the ICT and consumer electronics sectors. Our work suggests that the findings of this literature may not apply in other contexts. Instead, factors like links to certification, regulation, governmental policy, and societal stakeholders may be important. Future research may address this topic.
4. During the time in which we conducted our study, there have been parallel developments related to impact measurement. For example, in this period the Global Reporting Initiative has released a number of standards for measuring societal impact in specific sectors (GRI, 2022b). These standards were not yet available when we developed the underpinnings of our approach. Future research may take them into consideration.[74]
5. Geopolitical developments have initiated major disruptive processes in society while our project was underway. It remains to be seen whether and how this affects the role, which standards are expected to play, and their potential contributions to societal change. For example, governments may take the lead more often, or may decide to leave societal developments to other actors. In either case, standards have

[74] Our recommendation on awareness of competing standards (Section 9.5.7) directly applies to this context: Our findings about ISO 14064-1 (GHG emissions) and ISO 14044 (life-cycle analysis) raise the question whether ISO should be involved in developing standards in this area.

the potential to be important, but their contribution is likely to differ. Future research on the topic should pay close attention and reflect new developments.

6. To reflect societal developments, new research may also take the "grand societal challenges" as a point of departure. Such research would take stock of all standards which are relevant for a certain societal problem, and assess to what extent they contribute to solving this issue. In doing so, it could build on our pioneering work in relating standards to societal change. It would therefore provide a more global overview over standards' relevance for society.

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11 Appendix

11.1 Research team

Paul Moritz Wiegmann is Assistant Professor at the Department of Industrial Engineering & Innovation Sciences at Eindhoven University of Technology (TU/e), the Netherlands. He obtained his PhD about the relationship between standards and innovation in 2019 from Rotterdam School of Management, Erasmus University. Paul's research and teaching are motivated by the observation that grand-societal challenges and other major societal and economic issues (e.g., digitalisation) cannot be addressed by any single party alone. In particular, Paul investigates how standards and standardisation serve to align stakeholders in these contexts. Paul also serves as treasurer and is incoming president from January 2023 of the European Academy for Standardisation EURAS. His work has been published in prestigious outlets, such as *Research Policy* and a single authored book at Palgrave Macmillan, see https://research.tue.nl/en/persons/paul-moritz-wiegmann.

Henk J. de Vries is Professor of Standardisation Management at the Rotterdam School of Management, Erasmus University (RSM), and Visiting Professor at the Delft University of Technology, Faculty of Technology, Policy and Management, both in the Netherlands. His research and teaching focus on standardisation from a business point of view. He works for the endowed chair on standardisation since 1994, full-time since 2000. The chair is part of the Section Innovation Management of the Department of Technology & Operations Management.[75] In the period 1984-2000 Henk worked for NEN in several roles. He was President of the European Academy for Standardisation EURAS until recently. He is (co)author of more than 400 publications in the field of standardisation, see http://www.rsm.nl/hdevries. In 2009, ISO awarded his education about standardisation as best in the world.

Doyoung Eom is postdoc at the Department of Industrial Engineering & Innovation Sciences at Eindhoven University of Technology (TU/e), the Netherlands. She obtained her PhD about standardisation in converging industries from the Graduate School of International Studies, Yonsei University in South Korea. Her research and publications focus on the relationship between standards and innovation in sectors such as automotives and healthcare, see https://research.tue.nl/en/persons/doyoung-eom. She taught digital business and standardisation to students in Yonsei University. She participated in multiple research projects on standardisation funded by the Korean government. The most recent projects were on standards cooperation with the Association of Southeast Asian Nations (ASEAN). She was awarded the first prize best paper at the ITU Kaleidoscope 2017 and IEC-IEEE-KATS Challenge 2018.

[75] The 2021 academic subject rankings of the Academic Ranking of World Universities (ARWU, 'Shanghai Ranking') puts RSM in first place for business administration.

11.2 Project deliverables, as specified in the agreed project proposal

1. Literature review

The topic of societal impact of standards is not absent in scientific literature. Probably the largest number of studies relates to the international standard for environmental management systems ISO 14001 – literature suggests positive, neutral or mixed impacts on the environment, even for this standard with a clear societal purpose (De Vries et al., 2012). Assessing impacts is not that straightforward. The literature review therefore does not aim to be exhaustive about impacts but provides an indicative overview. Next, it focuses on methods used.

2. Overview of cases of standards and their societal impacts

An explorative pre-study provides an overview of cases of standards. Dimensions of societal impacts are indicated in a qualitative way.

3. Assessment method

The assessment method will be presented in the form of a tool. It is developed based on the research team's expertise, expertise from colleagues at both universities[76], expert interviews, literature on standardisation but also on societal impact measurements in other fields (e.g., on measuring SDGs), and on the exploratory case study. A proper balance between thoroughness and ease of use has to be found. A draft method is tested in a few in-depth case studies (see Deliverable 4). These may lead to further improvements of the method.

4. In-depth studies of standards and their societal impacts

In-depth case studies provide empirical evidence of societal impacts of some standards. These are also used to test and validate the method.

5. Reporting

Deliverables 1-4 will be included in the written report. Moreover, this report provides recommendations on how to proceed. We expect that this will include the recommendation to create a database of cases linked to United Nations Sustainable Development Goals (SDGs). The latter should provide empirical evidence per SDG about the impacts of different categories of standards.

The team intends to report to and get feedback from the XXM Project Group during the project. Presentations to the CEOs are foreseen in March and November 2022 (assuming availability of a suitable postdoc researcher in September 2021): the first one with a focus on deliverables 1 and 2, the second one presenting the final report including the deliverables 3 and 4.

[76] E.g., RSM's Partnerships Resource Centre (PrC): an international research– and knowledge centre for public-private collaboration for sustainable and inclusive development, see https://www.rsm.nl/research/centres/prc/, and the Impact Centre Erasmus (ICE), part of the Erasmus University Rotterdam, that conducts research into impact thinking, impact measurement and impact management, see https://www.eur.nl/ice/impact/impact-measurement-english.

11.3 Presentations given to the XXM Partners during the project

Table 13: Overview over presentations to the XXM Partners

Date	Audience	Topics discussed
2021-11-23	XXM task force on societal impact	• Overview of the research plan • Update on the first phase of pre-study • Selection criteria and preferences for in-depth cases, XXM Partners nominated standards for in-depth studies after this meeting
2022-02-23	XXM task force on societal impact	• Update on student internships (destinations, topics, and standards), matches made based on students' and XXM Partners' preferences • Update on pre-study • Overview over literature • Request to XXM Partners to support data collection for in-depth cases, including distributing surveys to buyers of each standard
2022-03-11	XXM task force and experts at XXM Partners	• Presentation to XXM task force and colleagues at XXM Partners to give an overview of the student internships
2022-03-31	XXM task force on societal impacts	• Update on progress • Presentation of draft Logic Model • Details about content and distribution of survey discussed and agreed • Details of upcoming CEO meeting discussed
2022-04-19	CEOs	• Meeting cancelled
2022-06-01	XXM CEOs	• Project overview • Preliminary pre-study results • Scientific foundation for impact measurement • Update on ongoing work and first insights on in-depth case studies
2022-06-28	XXM task force and experts at XXM Partners	• Results of in-depth case studies (student presentations) • Initial insights across cases
2022-11-03	XXM task force on societal impacts	• XXM task force's feedback on draft report • Important findings not yet included in draft report • Reasons behind nominating standards for in-depth cases by XXM Partners • Suggestions for communicating final results to CEOs

11.4 Pre-study: list of 48 selected standards

Table 14: List of 48 standards included in the pre-study

No.	Standard	Title	ICS code	Criteria (See Section 2.2.1)	Notes[77]
1	NEN 8112	Internal emergency response	13.200	1	
2	IEC 62443-2-1	Industrial communication networks - Network and system security - Part 2-1: Establishing an industrial automation and control system security program	25.040.40 33.040	1	
3	ISO/IEC Guide 46	Comparative testing of consumer products and related services — General principles	19.020 03.080.30	3	ICS code 19
4	EN-IEC 61439-1	Low-voltage switchgear and control gear assemblies - Part 1: General rules	29.130.20	1	
5	EN-ISO 80079-36	Explosive atmospheres - Part 36: Non-electrical equipment for explosive atmospheres - Basic method and requirements	13.230 29.260.20	1	
6	EN-IEC 61000-4-2	Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test	33.100.20	1	
7	ISO 3184	Reach and straddle fork-lift trucks - Stability tests	53.060	3	ICS code 53
8	EN-IEC 60086-3	Primary batteries — Part 3: Watch batteries	29.220.10 39.040.10	3	ICS code 39
9	EN-ISO 14971	Medical devices - Application of risk management to medical devices	11.040.01	1	
10	EN-ISO 8559-1	Size designation of clothes – Part 1: Anthropometric definitions for body measurement	61.020	3	ICS code 61
11	NPR 9998	Assessment of structural safety of buildings in case of erection, reconstruction and disapproval – Induced earthquakes – Basis of design, actions and resistances	91.080.01 93.020	1	Free
12	ISO 31000	Risk management – Guidelines	03.100.01	1	
13	ISO 21384-3	Unmanned aircraft systems – Part 3: Operational procedures	49.020	3	ISO Focus 122
14	EN-IEC 62446-1	Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and inspection	27.160	1	
15	EN-ISO 14644-1	Cleanrooms and associated controlled environments – Part 1: Classification of air cleanliness by particle concentration	13.040.35	1	
16	EN 13445-1	Unfired pressure vessels – Part 1: General	23.020.30	1	

[77] This column shows from which missing ICS group we identified a suitable standard to have a variety of standards included in the analysis. It also shows which standards offered for free by NEN with the highest numbers of downloads were included.

No.	Standard	Title	ICS code	Criteria (See Section 2.2.1)	Notes[77]
17	NEN 1414-1	Symbols for safety precautions on drawings and plans – Part 1: Escape and rescue plans and intervention drawings	01.080.30	1	
18	EN 50128	Railway applications – Communication, signalling and processing systems – Software for railway control and protection systems	35.240.60 45.020 93.100	3	ICS code 45
19	ISO 45001	Occupational health and safety management systems – Requirements with guidance for use	03.100.01 13.100	1	
20	EN 206 + NEN 8005	Concrete – Specification, performance, production and conformity	91.100.30	1	
21	EN-ISO/IEC 27701	Security techniques - Extension to ISO/IEC 27001 and ISO/IEC 27002 for privacy information management - Requirements and guidelines	35.030	1	
22	NEN 5077	Noise control in buildings - Determination methods for performances concerning airborne sound insulation of facades, airborne sound insulation and impact sound insulation, sound levels caused by technical services	91.120.20	1	Free
23	NEN 2767-1	Condition assessment built environment - Part 1: Methodology	91.010.30 03.080.10	1	
24	EN 13031-1	Greenhouses - Design and construction - Part 1: Commercial production greenhouses	65.040.30	3	ICS code 65
25	NTA 8800	Energy performance of buildings - Determination method	91.120.10 91.140.30		
26	ISO 26262-2	Road vehicles - Functional safety - Part 2: Management of functional safety	43.040.10	1	
27	EN-IEC 60825-1	Safety of laser products - Part 1: Equipment classification and requirements	13.110 31.260	3	ICS code 31
28	NEN 1010	Electrical installations for low-voltage - Dutch implementation of the HD-IEC 60364 series	91.140.50	1	
29	EN-ISO/IEC 27002	Information technology - Security techniques - Code of practice for information security controls	03.100.70 35.030 35.040	1	
30	EN 15224	Quality management systems - EN ISO 9001:2015 for healthcare	03.100.70 03.120.10 11.020 11.020.01 11.020.10	1	
31	NPR 3378-1	Code of practice gas installations - Section gas pipework - Part 1: Determination of gas tightness of the gas installation - Guidelines for NEN 1078 and NEN 8078	91.140.40		
32	NEN 9997-1	Geotechnical design of structures - Part 1: General rules	91.080.01 93.020	1	

No.	Standard	Title	ICS code	Criteria (See Section 2.2.1)	Notes[77]
33	NEN 1006	General requirements for water supply installations	91.140.60	1	
34	EN-IEC 60204-1	Safety of machinery - Electrical equipment of machines - Part 1: General requirements	13.110 29.020	1	
35	EN-ISO 13485	Medical devices - Quality management systems - Requirements for regulatory purposes	03.100.70	1	
36	EN-ISO 15614-8	Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part 8: Welding of tubes to tube-plate joints	25.160.10	1	
37	EN-IEC 62305-4	Protection against lightning - Part 4: Part 4: Electrical and electronic systems within structures	29.020 91.120.40	1	
38	NEN 5707	Soil - Investigation and sampling of asbestos in soil and soil stockpiles	13.080.01	1	Free
39	EN-ISO 12944-1	Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 1: General introduction	87.020 91.080.13	1	
40	CEN/TS 16937	Nanotechnologies - Guidance for the responsible development of nanotechnologies	03.100.02 07.120	3	ICS code 07
41	ISO/TS 15311-1	Graphic technology — Requirements for printed matter for commercial and industrial production — Part 1: Measurement methods and reporting schema	37.100.01	3	ICS code 37
42	EN-ISO 50001	Energy management systems - Requirements with guidance for use	27.015 03.100.70	1	
43	EN-ISO 22000	Food safety management systems - Requirements for any organization in the food chain	67.020 03.100.70	1	
44	EN-IEC 60601-1	Medical electrical equipment - Part 1: General requirements for basic safety and essential performance	11.040	1	
45	NEN 3650-1	Requirements for pipeline systems - Part 1: General requirements	23.040.10	1	
46	NEN 5740	Soil quality - Strategy for exploratory survey - Investigation of the environmental quality of soil and soil lots	13.080.05	1	Free
47	ISO/IEC Guide 98-1	Uncertainty of measurement — Part 1: Introduction to the expression of uncertainty in measurement	17.020	3	ICS code 17
48	EN-ISO/IEC 17025	General requirements for the competence of testing and calibration laboratories	03.120.20	1	

11.5 Methodological information about the review of ISO 9001's and ISO 14001's impacts

We identified academic literature about ISO 9001's and ISO 14001's impacts in the 'Web of Science' and 'Scopus' databases. To do so, we used the search terms shown in Table 15. Subsequently, the identified papers were screened, based on the following inclusion criteria:

- The paper focusses on ISO 14001 or ISO 9001,
- The paper discusses impacts of the standard in the broadest sense (e.g., societal, environmental, economic),
- The paper is written in English,
- The paper is published in peer-reviewed sources (journals, conference proceedings, books),
- The paper was published between 1996 and 2022 (ISO 14001) or between 1987 to 2022 (ISO 9001),
- The paper reports empirical research.

The full-text of all papers meeting the inclusion criteria was read and the contents were coded. In coding, we recorded information, such as the identified impacts, the empirical setting of the study, and key methodological choices.

Table 15: Search terms used in the review ISO 9001's and ISO 14001's impacts

ISO 14001	ISO 9001
("ISO 14001" OR "ISO14001" OR "ISO 14000" OR "ISO14000") AND (impact* OR effect* OR benef* OR valu* OR perform* OR advantag* OR influenc* OR sustainab* OR innovat* OR diffus* OR implement* OR adopt*)	("ISO 9001" OR "ISO9001" OR "ISO 9000" OR "ISO9000") AND (impact* OR effect* OR benef* OR valu* OR perform* OR advantag* OR influenc* OR sustainab* OR innovat* OR diffus* OR implement* OR adopt*)
("environmental management system* standard*" OR "environmental management standard*") AND (impact* OR effect* OR benef* OR valu* OR perform* OR advantag* OR influenc* OR sustainab* OR innovat* OR diffus* OR implement* OR adopt*)	("quality management system* standard*" OR "quality management standard*") AND (impact* OR effect* OR benef* OR valu* OR perform* OR advantag* OR influenc* OR sustainab* OR innovat* OR diffus* OR implement* OR adopt*)

11.6 Detailed reports of the pre-study and the in-depth case studies

The study into the potential effects of the 48 selected standards (see Chapter 5) and the eight in-depth case studies (see Chapter 6) were completed by students of Rotterdam School of Management, Erasmus University as part of their master-thesis trajectories. The complete master theses written by the students are provided alongside this project report.

11.7 Overview of the detailed stakeholder identification method

The following provides an overview of the detailed stakeholder identification method's main steps.[78]

1. Identify the purpose of the standard and the entities to be (re)shaped.
2. Draft a rough value chain for each entity:
    a. Development chain (e.g., design of components, design of modules, design of final product);
    b. Production (e.g., delving raw materials, production of materials, production of components, production of modules, assembling the final product);
    c. Use (business use or consumer use, recycling/re-use/waste-handling);
    d. Support: support for design (e.g., university research), support for production (e.g., advice, maintenance), support for use (e.g., help-desk);
    e. General: conformity assessment, inspection, regulation, education, activities of special interest groups, complementary or competing standards development.
3. Link stakeholder categories to each of these activity categories (e.g., chip supplier, consultancy firm, certification body).
4. Distinguish these, if applicable, in:
    a. Individual (e.g., Auditor);
    b. Organization of individuals (e.g., Association of auditors);
    c. Organisation in the chain (e.g., Certification body);
    d. Association of organisations (e.g., Association of certification bodies).
5. Create an overview of all identified stakeholders by putting them in a matrix: The rows represent one of the five categories mentioned at 2. The columns define the four categories mentioned at Step 4.
6. Fill in each cell of the matrix as specifically as possible. If possible, add names of individuals (only core experts, if any, are relevant) and organisations.

[78] Original source: Verheul, Hugo & Henk de Vries (2003) *Verbetering formele normalisatieproces*. Delft: Centre for Process Management and Simulation. Also described in: De Vries, Henk J., Hugo Verheul & Harmen Willemse (2003). *Stakeholder* identification *in IT standardization processes*. In: John L. King & Kalle Lyytinen (Eds) *Proceedings of the Workshop on Standard Making: A Critical Research Frontier for Information Systems.* Seattle, WA, December 12-14, 2003, pp. 92-107. http://www.joelwest.org/misq-stds/proceedings/ICIS2003-misq-stds.pdf.

11.8 Overview over commonly used indicators for measuring societal impact

Table 16: Overview over commonly used indicators for measuring societal impact

	Main users	Format	Aspects considered	Level/scope	Timing	Reference to SDGs	Strengths	Limitations
UN CSD (United Nations, 2007)	• National policymakers	• Guidelines • Framework • Indicators	• Outcomes • Issues	Countries	Ex-ante & ex-post	MDGs	• Indicators are grouped into issues or themes relating to sustainable development	• Indicators do not reflect the transformation from MDGs to SDGs
IAEG-SDGs (United Nations, 2022)	• National policymakers • Int'l organisations • Investors • Businesses	• Indicator framework	• Activities • Outcomes	Countries	Ex-ante & ex-post	Yes	• Tier classification • Metadata repository	• Changes (expressed in terms of outcomes and impacts) are not captured by SDGs that describe areas of action • SDG targets are a mix of outcomes and activities
SDR (Sachs et al., 2021)	• National policymakers • Int'l organisations • Investors • Businesses	• Indicators	• Outcomes	Countries	Ex-ante & ex-post	Yes	• Bridges data gap	• Changes (expressed in terms of outcomes and impacts) are not captured by SDGs that describe areas of action • SDG targets are a mix of outcomes and activities
GRI (GRI, 2022)	• Any organisation regardless of size, type, etc. • Investors • "information users"	• Disclosure requirements (sets of indicators)	• Impacts on the economy, environment, and people	Organisations	Ex-post	Yes	• Principle of materiality to use for the selection of relevant, significant outcomes	• Disclosure requirements are a mix of processes, outputs, and outcomes

	Main users	Format	Aspects considered	Level/scope	Timing	Reference to SDGs	Strengths	Limitations
IRIS+ (McCarthy et al., 2021)	• Main audience is impact investors • Can also be used by companies	• Methodology • Metrics • Sets of indicators	• Impact	Organisations	Ex-ante & ex-post	Yes	• "System" for impact accounting (categories, themes, strategic goals, metrics)	• "investable" SDG targets are covered with its metrics leaving out non-investable targets relevant to standards
HIPSO (HIPSO, 2022)	• Development Finance Institutions (DFIs) and their clients • In development contexts	• Framework • Indicators	• Outputs • Outcomes	Organisations	Ex-post	Yes	• Aimed at relieving the reporting burdens of clients • Harmonised with IRIS	• Poor online interface and a lack of supporting documents
IRIS and HIPSO (GIIN, 2021)	• DFIs • Multilateral development banks • Impact investors • Government agencies	• Indicators	• Impact	Organisations	Ex-post	Yes	• Harmonised with HIPSO and many other standards → increased comparability of data • Provides common languages in assessing impacts of investment operations	• Harmonised along three topics
UNEP FI (Timco, 2018)	• Financial institutions	• Principles • Indicators	• Impact	Organisations	Ex-ante & ex-post	Yes	• Impact categories in the impact radar are derived from the 3Ps • Library of indicators	• Mainly about the impact of financing that financial institutions provide

	Main users	Format	Aspects considered	Level/scope	Timing	Reference to SDGs	Strengths	Limitations
OCED Oslo Manual (OECD/Eurostat, 2018)	• Firms • Users of innovation data (academics, policy analysts, managers, etc.)	• Framework and guidelines for measuring innovation • Indicators	• Activities • Outcomes • Impacts	Firm	Ex-ante & ex-post	Not explicit	• Useful if the objectives of the standards and the activities derived from the standards are related to innovation • Innovation logic model	• Indicators are proposed to measure at the firm level
UNDP SDG Impact Standards (UNDP, 2021)	• Enterprises • Private equity • Bonds	• Guidance • Standards • Certifications (SDG impact seal)	• (decision-making) processes	Enterprises	Ex-ante	Yes	• Standards available for enterprises, private equity, and bonds • Self-assessment tool with practice indicators	• Guides enterprises on how they can contribute to the achievement of SDGs rather than how they can measure those actual achievements

Sources underlying Table 16

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