How to turn “less bad” into good without limit

To measure companies’ positive climate impact

Kajsa Eliasson

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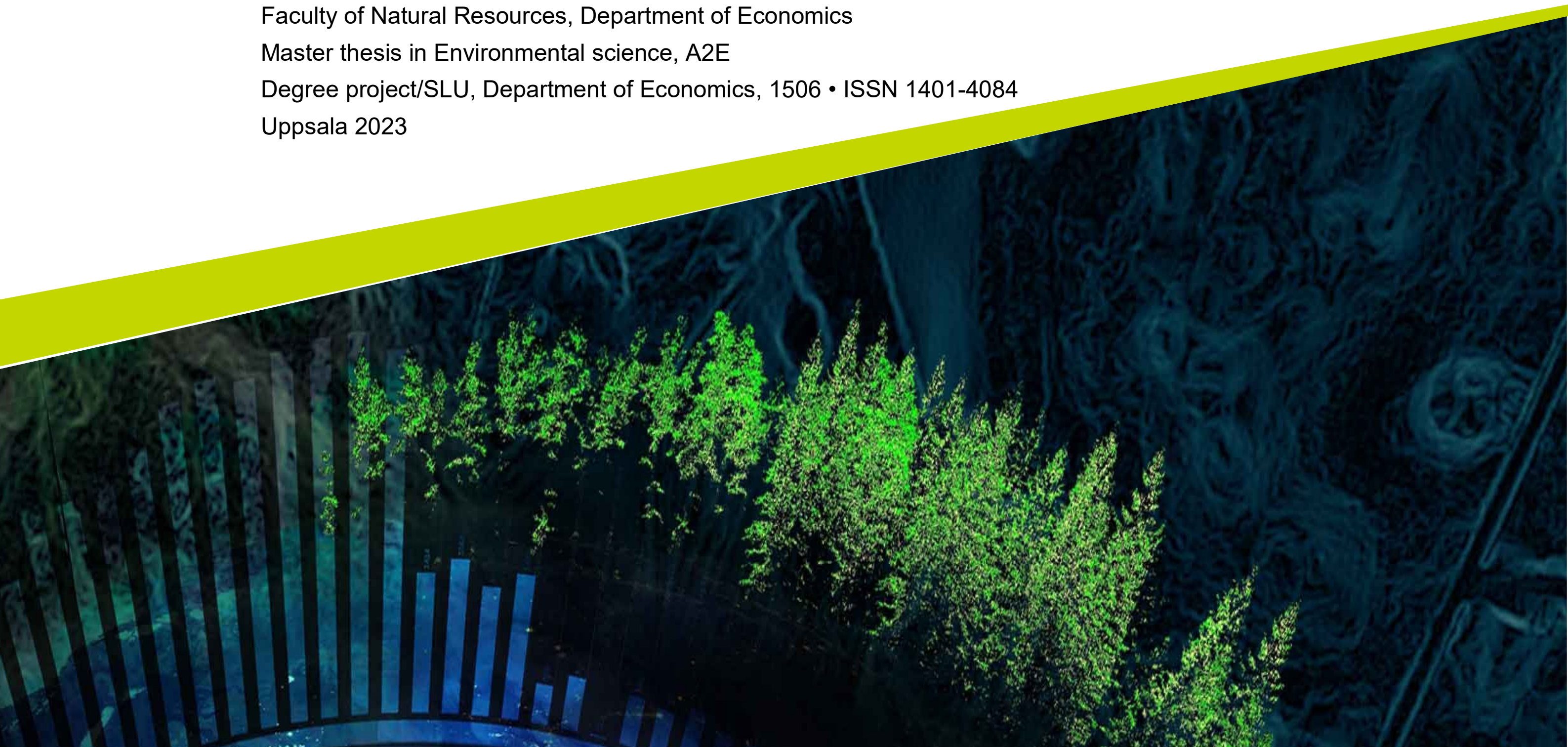

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Supervisor:	**Örjan Östman, Swedish University of Agricultural Sciences, Department of Aquatic Resources**
Assistant supervisor:	Dan Engström, Plan B
Examiner:	Hanna Astner, Swedish University of Agricultural Sciences

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Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Economics

Abstract

Climate change is an urgent problem threatening life as we know it. To combat the problem there is a high need to reduce this generation's human-induced Greenhouse Gasses (GHGs). Today's societies consist of complex networks of actors, and solving the problems of climate change will require contributions from all types of actors, not least from companies. At the same time as the expectations and the demands on companies' environmental responsibility are getting higher, measuring and reporting climate impact has become more and more common among companies. The currently most common approach for companies' climate impact is focused on doing less harm by lowering the company's emissions as close to zero as possible. The best possible outcome from a scenario where all companies stick to working within their own company's boundaries, using the "less bad" approach, is that some companies reach net zero. With the current degree of environmental harm, however, that would not be long-term sustainable. Instead, more companies need to raise their sights and also start looking beyond their own boundaries to see what more can be done. With such a shift, the focus does not only switch from guilt and burdens to opportunities but also removes the limit for how much positive climate impact a company can have.

There are businesses, like the digitalization consultancy sector, that have opportunities for achieving a positive climate impact since their own climate impact is vanishingly small in comparison to the climate improvements they can achieve through their operations. By working with reducing other companies' emissions, digitalization consultants can overcompensate for their own emissions, making it possible for them to achieve a net positive climate impact in comparison to a Business As Usual (BAU) scenario.

For solution providers, such as digitalization consultants to become profitable and get the distribution they need, there is a need for them to be able to measure and demonstrate their generated positive effect. In this thesis, ways in which positive climate impact can be measured and demonstrated by digitalization consultancy companies are investigated. The findings show that there are at least five terms in the industry, used synonymously to describe this positive effect, Scope 4, Avoided emissions, Enabling effect, Carbon handprint, and Comparative emissions. Findings also show that there are existing frameworks and methods available, that theoretically are capable of quantifying this positive effect. The thesis suggests three frameworks that seem to be most suitable for digitalization consultants, and among these, the most comprehensive is the Avoided Emission Framework (AEF) provided by Mission Innovation. All of the founded frameworks do, however, come with practical challenges, for instance, related to the required data, the measurement techniques, and the need of making future predictions. Further, since one of the main purposes of the assessments is to enable comparisons based on the climate capacity of different alternatives, the lack of real applications makes the contextual field missing, making any given outcome from current methods difficult to use and hard to interpret. This dilemma raises the question of whether it is best to start using a framework that contains challenges and unsolved problems or wait until the perfect framework has evolved. This gets answered with the suggestion that companies preferable should continue exploring the field of Scope 4 by adopting a transparent approach, and keep testing out the methods to contribute to their further development.

Keywords: Digitalization, Avoided emission, Carbon Handprint, Scope 4, Building, Construction, Building 4.0, Consultancy, Project-based industries, Carbon assessment, Environmental impact, Environmental strategies

Popular Science Summary

The ongoing climate change is a serious problem, threatening life on earth as we know it, and comes with severe consequences both on the environment, on existing societal structures, and on the global economy. This motivates cross-border collaborations between different societal actors and makes it more important than ever before that companies increase their responsibility taken towards the climate. Some companies do not have any greater climate impact themself but have through their actions, great opportunities of helping other, more climate-burdening industries to lower their climate impact. By offering other industries climate smart solutions, the company can overcompensate their own negative climate impact, and thereby achieve a net-positive climate impact on society, in comparison to a scenario in which companies only address climate impact within their own company's boundaries. The demand for this type of service will probably become higher and higher, as the environmental requirements on companies are increasing. In addition, the achieved positive effects are beneficial to a collective plan, since it accelerates the overarching societal climate transition, and does thereby increasing the chances for humanity to decrease their climate impact to levels within the frames of what is long-term sustainable. For this type of business to be profitable, and thereby be possible to run to any larger extent, there is a need for well-functioning methods, tools, and frameworks that can quantify the positive result or the decreased climate impact. That is because the result constitutes the customers, investors, and stakeholders' main basis for assessing the profitability of hiring the external company that helps them lower their climate impact. The customer or investor does, in other words, needs to be capable of balancing the costs of maintaining a climate-burdening business, which in parallel with increased environmental requirements for companies, will become more and more expensive, in comparison to the costs of hiring a company helping them reducing their impact.

In this multidisciplinary thesis initiated by the company Plan B, semi-structured literature studies, in combination with expert interviews are combined to investigate existing opportunities for digitalization consultancy companies, working with providing climate efficient solutions for their customers, to measure their positive generated effects. In addition, challenges and hindrances associated with the existing ways also are investigated. The purpose of the thesis is to contribute to the increased understanding of the current industrial situation, which are the existing needs, and what are the existing opportunities when it comes to working with positive climate impact.

The findings show that there are existing frameworks and methods available, capable of capturing these positive effects in theory. These are not mentioned in the scientific literature to any larger extent. Among the available alternatives, one of these, the Avoided Emission Framework (AEF), seems to be the most extensive and realistically designed. However, all the found frameworks do seem to be too simple to cover all of the important real-world problems, making existing frameworks currently too immature to fulfil the existing need of the industry. Regardless of that, the final suggestion is that companies within the digitalization consultancy sector still probably would benefit from keeping applying and testing out these frameworks, since these efforts over time, would contribute to an increased understanding of the frameworks, and thereby increase usefulness.

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Writing this thesis has been a long journey, and I feel honored when looking back at all the interesting people that I've met and had the chance to discuss with. In the acknowledgments, I would like to present my gratitude to everyone who with their time, knowledge, efforts, and support directly or indirectly contributed.

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Kajsa Eliasson

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Acronyms

AEF Avoided Emission Framework 1, 3, 4, 7, 19–21, 23, 27, 28, 31, 32

BAU Business As Usual 3, 18, 21–23, 27, 31

BIM Building Information Modeling 15

CEP Corporate Environmental Performance 36, 39, 40

CO2 Carbon Dioxide 1, 12, 14, 24

ESG Environmental Social and Governance 36, 38–40

EU European Union 1

GHG Greenhouse Gas 1, 3, 4, 7, 10–12, 14, 17, 20, 24, 25

ICT Information and Communication Technology 8, 25

IoT Internet of Things 15

IPCC The Intergovernmental Panel on Climate Change 1, 14, 30

ISO International Organization for Standardization 10, 11, 23

LCA Life Cycle Assessment 10–12, 20, 23, 25, 32

UN United Nations 1

VDC Virtual Design and Construction 15

WBCSD World Business Council for Sustainable Development 10

WBLCA Whole Building Life Cycle Assessment 11

WRI World Resources Institute 10, 20, 24

1 Introduction

Climate change is an urgent problem that comes with serious ecological, social and economical consequences. Melting glaciers, rising sea levels and extreme weather such as drought, fires, typhoons, and hurricanes are just a few examples.[1] There is a high need for humanity to reduce the generated levels of GHG emissions, and clear evidence of the need for more societal actors to start contributing and reducing their climate impact. The acute situation was pressed during the United Nations (UN)'s climate conference, COP26, with the message that all industries need to go further than current political actions, and that companies need to start providing clear metrics and assessments about their impacts on humanity to meet the planetary boundaries.[2] In The Intergovernmental Panel on Climate Change (IPCC)'s latest report, released in August 2021, there is also a call for action directed to society about how this pressing situation requires involvement from all kinds of actors.[3] That is addressed, not least in the enormous, currently emerging regulatory European Union (EU) taxonomy, which is an important part of the EU commission's action plan, The European Green Deal.[4]

Even though climate change is an issue with a lot of negative loads, it also comes with opportunities, not least for those whose business is based on helping others switch to more climate-friendly solutions. This can for instance be the case for the digital consultancy sector, which by providing digital solutions to their customers can help them increase their overall system efficiency.[5] Digital solutions and automatization processes seem to have several climate-beneficial abilities, such as the potential of lowering the energy- and material use and thereby catalyzing societal Carbon Dioxide (CO2) neutrality. The greatest climate potential for digital solutions seems to be when these are implemented in climate-inefficient industries.[6] The building sector is one example, a sector that is a large CO2 emitter, and at the same time is associated with conservative traditions and a low degree of new technical implementations.[7, 8]

The climate efforts taken can however be at a high risk of failing if companies can not develop proactive strategies, models, and practices for how the problem should be managed. For them to do that, careful, appropriate, and adequate methods for quantifying their climate impact are needed,[9] to provide great reference scenarios and guidance in the reduction process.[1] Currently available methods which assess companies' climate impact contain several challenges,[10] which aggravate environmental efforts as well as follow up the process of reaching the set environmental goals.[11]

1.1 Theoretical framework for knowledge production in multi-disciplinary fields

Within the academic world, an enormous amount of knowledge is available, and this constantly expands due to discoveries and research results.[12] The traditional academic disciplines have for a long period had a considerable positive impact on the scientific development, but parallel to this, major societal challenges constantly take place around the world. Globalization, digitalization, and economic development are increasing the linkage between people, countries, and places, and what used to be demarcated with distinguishing features has increasingly shifted to a global economy with more fluid boundaries and with new kinds of problems and challenges.[13]

> *"Science does not stand outside of society dispensing its gifts of knowledge and wisdom.; neither is it an autonomous enclave that is now being crushed under the weight of narrowly commercial or political interest."[12]*

Climate change, with its inherent complexity, is just one of many examples of such problems that can not be assigned to a single discipline. Schaltegger 2012 suggests that for scientists wanting to contribute to fighting climate change, only keep informing about the problem in publications will not be enough. For more constructive ways to deal with the problem, new types of holistic approaches will be needed.[14] As problems of multidisciplinary character get more and more common in our globalized world, a need for other forms of knowledge production has emerged. Gibbon described this and differed between what he referred to as Mode 1 and Mode 2 knowledge production.[12]

Mode 1 refers to the traditional scientific mode of knowledge production. The traditional academy has since the scientific revolution strictly been divided into fixed subjects, and has set demands on how methods, norms, ideas, and values must be followed and adhered to for results to be classified as ''good science". This knowledge production is more or less linearly performed and strongly adapted to the current discipline's interpretation of what constitutes knowledge.[13] It is affected by homogeneity and quality control exercised by hierarchical, stable institutions,[15] and even though Mode 1 has several advantages, it can also pose problems when it comes to coordination, organizational learning, and practical applications.[13]

Gibson suggests that some of today's research needs to be adapted toward societal changes in governance, by becoming more interactive, and open to collective and organizational learning. He also argues for the need to convince more researchers about the great advantages and mutual benefits given by involving more societal actors. To tackle and enable solutions to multidisciplinary problems, methods need to allow heterogeneity and cross-disciplinary approaches, and this is why he suggests a second mode of knowledge production, Mode 2.[13]

Mode 2 is knowledge developed with the application as its main goal. Mode 2 does, by challenging the assumed hegemony of traditional disciplines, constitute an approach, characterized by its ability to better address multidisciplinary fields,[15]that aims to facilitate and expand the societal applicability of the results.[13] Mode 2 is driven by the need to deal with practical problems meeting market needs.[15] In practice, the approach consists of a constant flow between what is considered basic- versus applied research, between theory and practice. When new results are found, they are transformed into new parts of the ongoing research process as extra driving forces for the continued search for new theoretical advancements. The research is reflexive and dialogical, more like an ongoing conversation between the researcher and the research subjects rather than a linear process.[12]

This kind of knowledge production needs to be both valued and prioritized so that emerging knowledge can be successfully converted into constructive societal benefits.[12] This, in turn, will require that all involved parties both can think and act to meet each.[13]

1.2 The Case of Plan B

The company which initiated this thesis was Plan B, a Swedish consultant company that provides digital solutions for the community-building industry. Their business model is based upon offering digital transformations for their customers, and their vision is to create a sustainable, environmentally friendly, and inclusive society.[16] This is shown in Figure 1.

A crucial aspect for a company, whose business idea relies upon helping others in different ways, is being able to demonstrate the positive effects of their services for the customers and stakeholders. In the case of Plan B, these benefits often consist of streamlining effects such as savings in energy- and material use or increased environmental performance. Therefore, Plan B is looking for a way to measure and communicate these positive sale arguments in a trustful, honest, and preferably quantitative way.

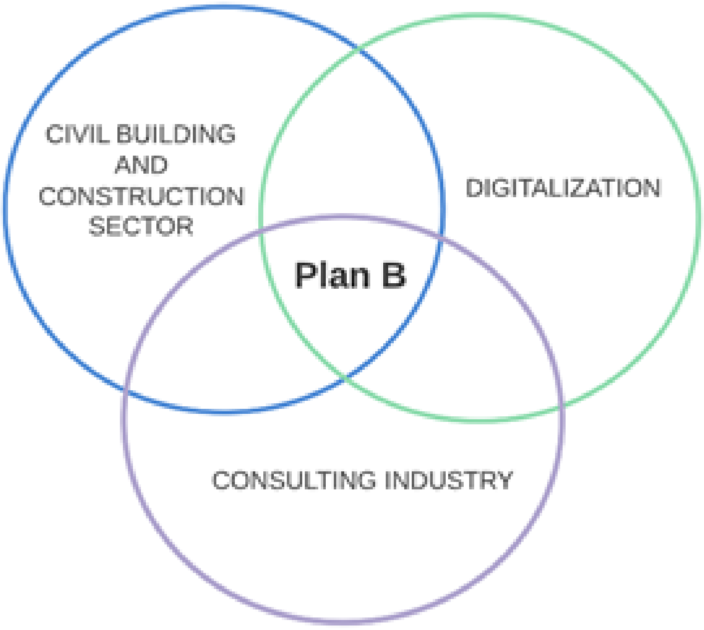

Figure 1: Illustration of main compounds of Plan B's business model.

Previous scientific contributions have already concluded that there are several ways in which companies can measure their climate impact and that for some actors, such as those within project-based industries, finding suitable assessments tends to be extra hard.[17] Further, since the building- and construction sector globally constitute one of the sectors with the largest climate impact, and suffers from general inefficiency, digital solutions may have the potential to decrease that impact.[7] Up to date, however, it seems to be a blind spot in the scientific literature about how actors that work with improvements in the digitalisation-consultancy sector can demonstrate the positive climate impact gained from their operations.

1.3 Research Questions

This thesis is closely related to the ongoing societal development. The aim of the thesis is to contribute with knowledge and best practices of measuring GHG avoidance to the state of industry, by providing actors in the construction and building industry guidance on how they can assess their positive climate impact generated by emission reductions in other sectors.

To address this problem, this thesis investigates the interface between the needs of the industry, and existing methods for assessing companies' positive climate impact, which requires a multidisciplinary research approach. I first review the current state of the art of relevant research fields in order to provide the theoretical and empirical understanding of the problem, (Mode 1). Secondly, I investigate the state of the industry by addressing actors within digitalisation to their needs and seek for ways consultancy companies can measure and demonstrate their positive climate impact, (Mode 2).

RQ1 Which existing opportunities are there for digitalization-consultancy companies to measure and demonstrate their positive climate impact?

RQ2 What challenges currently seem to be associated with existing ways of measuring positive climate impact for digitalization-consultancy companies?

2 Methods

This thesis combines a semi-structured state-of-art literature review, with an investigation of the state of industry through data collection from both primary and secondary data sources. Traditional academic disciplines have for a long period had a considerable positive impact on scientific development. An academic discipline provides the researcher with fixed reference frames, technologies, topics, and theories, but also comes with its languages and concepts, well recognized among other researchers in the same field.[18] Environmental science, however, is a subject that covers many scientific branches and different research approaches.[19] Environmental science could be considered a cross-disciplinary academic field that brings together parts from both ecology, geology, meteorology, biology, chemistry, engineering, and physics, to better understand environmental problems and human impacts on the environment.[20] This thesis also applies economics and communication, which are sub-disciplines within Social science. These are applied for instance in the parts that examine companies' opportunities and approaches towards environmental- and sustainability communication and strategies, as well as the solution-provider's opportunities to communicate their positive achieve results. Therefore, my work is related to Sustainability science, described as more of a goal and umbrella rather than a single discipline, merging several disciplines, domains, and scales, such as nature, society, democracy, science, global, local, history, future, and possible future.[18]

This means that this current thesis spans several academic disciplines, and thus claims multidisciplinary, a word which according to Pellegrino[21] has been described as a buzz word in some of the contemporary research.

For multidisciplinary science to succeed, there is a need for collaborative approaches that bring people and ideas from different disciplines together and agree on methodological approaches,[18] and this leads to some researchers suggesting that future research to a higher extent will be so-called Mode 2 research.[12]

2.1 Qualitative Primary Data Collection

In this thesis, I aim to find qualitative different ways in which environmental assessment can be done rather than calculate- or determine any quantities of impacts. Qualitative research comes in many different forms, many times with field components.[22] This makes qualitative research suitable when investigating case studies since case studies aim to examine certain persons, groups, programs, or issues, which all require some degree of field components.[23] Qualitative research is flexible and allows one or several elements of both case studies, as well as introspection, interviews, personal experience, cultural texts, and productions. The data are collected more spontaneously in natural settings, resulting in methods that are less structured and controlled in comparison to quantitative methods. There have been objections raised towards the validity and replicability of qualitative research, in contrast to the often stricter quantitative methods. On the contrary, the suitability of using quantitative approaches in social studies has also been questioned.[22]

2.1.1 Primary Data of Non-literature Data-sources

The primary data I gathered, comes from semi-structured interviews with experts, together with more informal information collection with the experts through conversations emails, and phone calls. In addition, I have also used recorded webinars.

To gather sources of industrial primary data, I reached out to 11 industrial companies´ sustainability departments through email. Among those five 5 were answering. Based on their relevance, three of these were further interviewed either by phone calls or emails and provided guidelines in the information search. The primary data sources formed an important part of the information gathering and led to many findings from secondary data sources(reports, websites).

In addition, 10 standalone people of high relevance were contacted. These were found either as suggestions from previously interviewed persons or mentioned by secondary data sources.

2.1.2 Expert Interviews

Expert interviews are useful when complex topics are investigated since their positions as experts offer them an exclusive capacity to analyze the research field in a meaningful way.[24] In this thesis, due to the multidisciplinary subject, and knowledge gaps, interviews constituted an important component of guidance. Experts were not only capable of offering valuable guidance of literature but also communicating experiences yet not well documented. The interviews were digitally conducted by using Microsoft Teams, and since the purpose of the interviews was to fill potential gaps of knowledge, there was a need to design them as open and flexible as possible. A few open questions about the expert's backgrounds, their introductions to the concept of Scope 4 (see section 5.1), and their thoughts about Scope 4 were prepared in advance, but were not followed strictly, and constituted more of a security to fall back on rather than a strict manuscript that was followed. The interviews were documented in writing rather than recorded, and the data collection consisted of analyzing these notes. I used this approach instead of recording the interviews to ensure the interviewees would feel comfortable and experience an open environment rather than being placed in a strict arena, to allow them to be reflective and think out loud. The interviews were conducted in Swedish and has been translated into English afterward. For each statement that has been used, the interviewees have been requested to confirm that the interpretation is correct.

The Experts

Patrik Halvardsson: Halvardsson is a board member of Digitaliseringskonsulterna with a leading position in the part working with AEFs. Halvardsson has a background in a variety of consultancy positions, and is currently, besides his position at Digitaliseringskonsulterna, working with climate- and energy-related questions at his own company, Aliego Consulting AB.[25]

Johannes Morfeldt: Researcher at Chalmers, working for the department of Physical resource theory with his orientation towards consumption-based emissions and emissions related to cases of future consumption.[26]

Joakim Pilborg: Pilborg works as head of sustainability at Knowit AB, a company of relevance for this thesis due to their position on the area of avoided emission. He has previously been involved in Digitaliseringskonsulterna and is one of the co-founders of their group that works specifically with avoided emissions.[27]

David Bastviken: Bastviken works as a professor at Linköping University in the department of Thematic Studies- Environmental Change. Bastviken's profile is partly oriented toward measuring GHG fluxes. He has recently published the report Measuring GHG fluxes; what methods do we have versus what methods do we need?[28]

2.1.3 Webinars

To fill information gaps, and due to the challenges of getting in touch with relevant interviewees, webinars also constituted an important source of information.

Webinar-lecturer

Dennis Pamlin: Pamlin constitutes an important key actor for this thesis due to his position as a predecessor for many of the findings which currently exist. Pamlin describes himself as an entrepreneur and founder of 21st Century Frontiers. He has a background in engineering, industrial economy, and marketing, and his primary skills are to work as a strategic economic, technology, and innovation advisor related to sustainability for companies, governments, and other organizations. Some of his previous positions which are relevant for the thesis are senior advisor at RISE, Global policy advisor at WWF, and has led the solution-providing work for many high-tech companies in the Information and Communication Technology (ICT) sector.[29]

2.1.4 Information Through Email and Phone

Some of the information was gathered by compiling received emails from relevant actors, as well as through a few phone calls.

2.2 Secondary Data Sources

To address Research question 1 about existing methods and concepts for digitalization-consultancy companies to measure positive climate impact, I review the current scientific literature. Due to technical advancements, there is a high proportion of available compiled information which can easily be applied to research. Secondary data consists of information that previously has been conducted by others, and may therefore require additional critical evaluation by the researcher before it is used to evaluate in what context and purpose the information is being used, and how it has been sampled. This is especially important in the case of non-scientific literature and data, i.e. data sets and publications that peers have not independently reviewed.[30]

In this study, secondary data constitutes a crucial part of the information. This was especially important for the conduction of the literature review on the state-of-art, which best can be described as a semi-systematic review.

Semi-systematic reviews are suitable for investigating complex topics and aim to overview the subject and thereby identify and understand previous and relevant findings about the researched topic.[31] The findings for the literature review consist of scientific literature on environmental strategies, environmental indicators, digitalization, the building sector, project-based industries, the various industries' practices and impacts, and the scientific evidence and incidence rates of different methodologies for assessing climate impact. The searches were conducted by using the platforms Web of Science, Scopus, and Science Direct (Elsevier), and documented by noting how many hits each search received. The literature search lasted for 7 weeks and ended on the 19th of October 2022. Up to this date, new literature of relevance was constantly being published. Appendix A constitutes a precise document describing the searches in detail. Due to the ongoing transformative changes in the field, literature published before 2005 has been excluded. Moreover, only literature in English and Swedish was used.

Other secondary data sources that have been used during the conduction of the report are sustainability reports, financial reports, websites, articles, books, newsletters, documents, and project documents.

2.3 Ethical Considerations

Since the thesis is closely related to the industry, many names of actors have occurred during the process. I choose to not anonymize names, since the involved persons are linked to a function (e.g. CEO Board members, researchers) that is of relevance in terms of what has been said. All participants have agreed to occur with his or her name.

3 State-of-the-art Literature Review

In this part, I have gathered insights from the literature on four different areas to position this contribution.

1. Companies' and their environmental strategies
2. Environmental assessments of project-based industries
3. The building industry and its environmental impact
4. Digitalisation as a climate solution

3.1 Companies and Their Environmental Strategies

Companies are important actors in global sustainability efforts, and literature regarding societal transitions has suggested that companies, as a part of multi-level perspectives in socio-technical systems, have great opportunities for sustainable shifts beyond their own intermediate boundaries.[32] Companies' environmental efforts are often embedded in the merged concept of sustainability, which involves both economical, social, and environmental aspects. Most researchers agree that in order to meet real sustainability needs, the priority order needs to be environmental $\rightarrow$ societal $\rightarrow$ economic aspects.[24]

Research has further shown that companies reporting on their environmental impacts, in some cases automatically lower the negative impact due to awareness of improvement potentials, increased environmental motivation among the employees, and positive synergies between different parts of the company. This means that the reporting itself can constitute a part of the total environmental strategy.[33] Since 1993 until today, the number of great companies reporting has increased from 12 percent to 80 percent. The frequency varies between industries, and the highest degree is seen in impact-heavy industries such as the technology-, oil-, health- and automotive industries, where the reporting proportion is 100 percent.[11]

One common way for companies when conducting their environmental strategies is to evaluate their own footprint of different environmental aspects, and then set up goals and strategies on how those impacts should be reduced. The most frequently used footprints that are reported upon are ecological-, carbon-, environmental-, water,- nitrogen-, ethical- and social, footprints,[33] but because emissions of GHGs are assumed to constitute the greatest threat towards increased global warming, integrating carbon emission reductions in the business strategies has turned into a common part of companies environmental strategies.[34] Even though there seems to be an almost endless array of initiatives, suggestions, methods, frameworks, lists, and guides available for helping companies with their environmental contributions, the most commonly adopted frameworks and methods are focused on the company's own, the negative impact and how that can be reduced. These types of assessments are often historical, looking back in time on emissions that already have appeared. The dominating goal is in other words to become less bad by lowering the current degree of negative impact. To become ''less bad'' does still mean harming the environment, and even if some companies can claim net-zero impact, science shows that with the current degree of harm, net-zero impact among some actors is probably still not enough to be sustainable. The focus on the negative environmental impact is currently the dominating way to approach environmental assessment, and a recent study shows that the current scientific state for assessments of positive environmental contributions is fragmented and almost non-existent.[32]

3.1.1 How Do Companies Currently Measure Their Carbon Impact?

There are several ways in which companies can assess their climate impact, and depending on the company's structure and demands, some methods are more suitable than others. The most frequently used one on the company level is the GHG protocol, developed by World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD). This comes in two separate parts, one for product life cycle accounting and one for corporate accounting and reporting standards. These are free, and use emission factors to decide the company's generated emissions.[33]

International Organization for Standardization (ISO), which globally constitutes one of the greatest developers of international standards, also provides standards that are highly used. For companies, to measure their GHGs, ISO 14064 is relevant. In comparison to the GHG protocol, neither of the ISO standards is freely available.[34]

For product-oriented companies, different types of Life Cycle Assessments (LCAs) or Cradle to grave analysis are commonly used. LCAs are comprehensive methods used to assess the climate impact mainly generated from end-consumer products.[34] An LCA provides a complete picture of inputs and outputs for a certain product and generates air pollutants from each stage. When conducting LCAs there are standardized methods to choose between. For buildings and greater projects, Whole Building Life Cycle Assessments (WBLCAs) are commonly used. WBLCA compiles results given from several LCAs to provide a full covering picture.[35, 36] Carbon footprint is another measure that can be described as an easier version of an LCA which consists of the direct and indirect emissions generated by a product, business, or organization.[37]

Beyond these, there are several existing online calculators which can be used by individuals, organizations, or businesses, most of them based on the GHG Protocol. Research made on these calculators has shown that the validity between them seems to be relatively high, but the reliability of their results on the other hand is low. Suggestions for using these are therefore that these alternatives can be helpful if the company chooses one of them, and sticks with that, and that provided results only should be compared within the same company, and not with external alternatives.[33]

The levels of detail in existing initiatives are varying. Some are more detailed assessments, requiring more data and time, and can even be too complicated for the company itself to carry out. For standards, such as ISO, EMA, and the GHG protocol, one requirement to get the certification, is to get the calculations reviewed and validated by an external party.[38]

Greenhouse Gas Protocol, Scope 1-3

The GHG protocol is, as mentioned, the current leading method for assessing a company's carbon footprint. One of the essentials of the method is the invention of the currently well-used division of the business impacts in levels of different "Scopes" before deciding the emissions for each of them.

The three widely accepted scopes are:

- Scope 1 The company's direct emissions, owned by the company itself. It can for instance be emissions from their vehicles.
- Scope 2 The indirect emissions derived from the production of the energy that the company is using, such as emissions generated from burning fossil fuels for electricity.
- Scope 3 Other indirect emissions, compiled in this voluntary category. It can be emissions up or downstream in the life cycles of the provided item, such as emissions generated by the material extraction or product use.[33]

3.1.2 Challenges In Measuring Carbon Impact

To develop strategies for emission reductions, there is a need to know the current levels of emissions generated by the company, something which often is complicated. Previous literature has suggested that the meaningfulness and appropriateness of GHG accounting depend on the ability to correspond to real-world situations, and constitute appropriate material for decision-makers and investors.[10] There is also a clear correlation between what is being measured, and what is being handled, which motivates the need for correctly adapted measurements.[32] Generating data can be both expensive, difficult, and time-consuming, and since there currently is a lack of enough detailed data on a local and national scale, there is often a great need for assumptions.[9] Data is sometimes borrowed, something that is common in many LCA studies,[39] but for the assessment to be correct, a sufficiently high correspondence between the real scenario and the data used is required, since the provided result only can be as reliable as the data they are generated from.[32]

A crucial aspect for the company is to evaluate which type of gases constitute their main climate impact. Some methods include all sources of GHG emissions, while others only focus on carbon emissions. Reflecting on this is relevant to achieve a proper assessment. For many companies, carbon emissions might constitute a great part of business-generated emissions, but the fact that gases such as CH4, N2O, HFC, PFC, and SF6 are very potent gases, even smaller emissions of these can have a large negative contribution.[1] Most methods for emission assessments provide quantified CO2 in the mass units kg/ton, or CO2-equivalent.[33]

The variety in legal requirements on companies' environmental efforts- and the need for them to communicate their impact are other challenges, leading to inconsistency between companies' climate efforts and their assessments.[40] This has led to concerns about the adequacy of companies' reported emission assessments. When comparing across diverse industries, there is an even greater lack of comparability between the assessments of GHG emissions, related to the embedded differences between the industries that complicate the legislation and leave organizations with greater freedom of choice.[10]

The purpose of something being a standard is to minimize differences and margins of error-, to achieve comparability between different results from assessments,[41] because a standard can increase the accuracy and consistency of the calculations. In theory, research has shown that a standard not can be viewed as a bulletproof guarantee for comparability between companies. Even if all companies should measure their GHGs following standardized GHG protocol, there still seems, within the boundaries of what is considered to be correct reporting, to be room for the glorification of the companies' performance, giving the results an aggravating margin of error. This will not only challenge the comparability between companies, but also complicate the comparability within the same company.[10] Even when applying the same method at the same company twice, internal changes in the value chains, such as outsourcing of carbon-intensive parts,[42] or changes in who is responsible for the reporting, has been shown could leading to differences in the interpretation on how and what should be reported on.[1]

Wegener (2019) described the climate assessment's methodological design as a contradictory camp between homogeneity and flexibility, and the result as a summary of two paradoxical characteristics. When a company wants to assess its emissions, all parts of the company needy needs to be included in the accounting of its generated emissions. This requires involvement from several actors, contexts, and phases before a result can be achieved, resulting in a complex network of actors and practices that the method needs to be capable of reflecting the dynamics of. On the contrary, there is also a need for homogeneity and standardization to obtain unitary assessments with relevant information.[10]

3.2 Environmental Assessment of Project Based Industries

One-fifth of global economic activities appear in project forms. Some of the great major actors in the category are the film industry, the construction- and building industry,[43] and not least the consultancy industry.

Project-based industries' operational keywords consist of flexibility and dynamics, and actors within the industries are used to working processes with non-standardized routines.[17] Some project-based organizations tend to suffer from fragmentation, for instance, the building sector, which divides the building phase into separate phases, all with their own specialized actors and production processes. The lack of common strategies, guidelines, standards, and agreements,[44] makes it difficult for organizations to define their environmental boundaries. Due to each project's uniqueness, and sometimes a shortage of environmental data, these industries tend to struggle more in the assessment of their environmental impact than manufacturing industries.[7] The usually occurring lack of repetitions and established practices in project-based industries also aggravate the employees' learning of existing environmental policies harder, making it easier for mistakes in assessments to occur. This is not only a problem for the company and the staff, but also for policymakers irregularities within-, and between different businesses, complicate the licensing authorities' establishment of environmental standards.[8]

Even though there often seems to be a great potential for knowledge-sharing between projects, which could increase the efficiency in harmonizing environmental assessments, this is not practically being applied to any greater extent.[17] That makes important information isolated and results in that feedback defaulted, which lowers the overall efficiency, and aggravates the development of well-functioning emission assessment methods.[2]

3.3 The Building Industry And Its Environmental Impact

Globally, the building sector is one of the largest business sectors with a financial turnover equivalent to around 13 percent of the global GDP, but the industry also deviates due to its significant environmental impact. As much as 40 percent of the global CO2 emissions can be attributed to the building industry, derived from the heating, cooling, ventilation, air conditioning, lighting, hot water supply, and embodied energy in materials built into the buildings.[45] The industry is also among the most resource-demanding industries. It uses huge amounts of natural resources and fossil fuels, and generates large amounts of waste, partly due to its difficulties with specifying future needs, resulting in frequent underestimations in budgets, and a high degree of waste material.[45, 46] Due to the current environmental problems, there is an urgent need for the sector to drastically reduce its environmental load. At the same time, the demand for the sector to keep delivering buildings and housing to meet the current population growth, is probably higher than ever before, which means the sector should produce more with less impact.[2] The building- and construction industry is further associated with a high quantity of work-related accidents, making the sector currently face great challenges not only related to the environment but also to ensuring occupational security.[43, 7, 8]

3.4 Digitalisation As a Climate Solution

Activities related to energy use and energy production have been shown to constitute a great part of all global GHG emissions, which is why energy reductions have been proposed as one of the most effective ways for reducing the levels of GHG emissions.[2, 47] Energy reduction in the building and construction sector can be achieved in different ways, but IPCC argues that one effective way is through digitalization implementations. At the same time, IPCC argues that humanity still has a limited understanding of the direct- and indirect climate effects of digitalization technologies and that there is a need to investigate these effects more.[3]

Previous research on climate impact from digital implementations has found that it has the potential to lower energy use in all end-use sectors by increasing energy efficiency and can be applied to most industries.[48] Substituting analog and physical processes with digital- and automated solutions has therefore been suggested to be an effective way to mitigate climate change.[49] By working with automatizing implementations and digital strategies for increased efficiency in the industrial,- manufacturing, and agriculture sectors, 4 % of the global GHG emissions is suggested to be possible.[46] These efforts could for instance consist of integrating smart devices into previously manual processes, or implementing analytical business models in the building- and construction sectors, making it possible to reduce energy spills and maximize precision.[49]

An additional aspect of digital solutions is the potential for projects to be both accelerated and up-scaled quickly. This was proven, not least after the Corona pandemic, where digital transitions enabled distance work, and replaced many of the previously resources-demanding day-to-day habits, forcing the world to think in new pathways.[46] This shows that digitalization can, not only help increase efficiency but also tackle the high presence of urgency when it comes to finding solutions and distributing them rapidly to enable reduced emissions. The time factor in being capable of eliminating long transition periods or skipping whole steps in the process toward climate-efficient solutions, constitutes, in a sense, an additional positive environmental aspect.[50]

3.4.1 Digitalization In The Building- And Construction Sector

Despite the described opportunities with digitalization, digital solutions are relatively absent in some of today's most energy-demanding industries, and the level of digitalization is in many areas still at an early stage.[2] The building industry is one example, associated with conservative traditions and a low degree of new technical implementations.[2, 7, 8]

The act of implementing digital technologies in the building- and construction sector is sometimes referred to as building 4.0 or construction 4.0. This act of implementing digital technologies and cyber concepts in the processes is the single most important change occurring in the sector. It not only revolutionizes the opportunities of increasing resource efficiency throughout the whole life cycle of a building, by lowering the use of energy, and natural resources and improving waste management.[7] It also enables continuous information exchange between all the involved actors in the construction process. A couple of sectoral well-recognized examples are Building Information Modeling (BIM), Virtual Design and Construction (VDC), digital processes developed to help with strategic aspects, information exchange, and coordination between actors involved in the process.[44]. Another example is digital twins, which in the construction sector can serve as a link between the digital and physical world, by connecting sensors and Internet of Things (IoT) devices that collect data about the physical object in real-time[51]. Digital twins can be used in a variety of ways, and constitute a helpful tool that based on real-time visualization- and communication could perform things such as removing hazardous waste from the construction site,[52] but also optimize processes such as lowering the energy consumption, the time used or the costs.[51]

The overall use and implementation of digital means also seem to increase working-environmental safety, improving overall construction and decreasing project costs.[49] Thus, there seem to be good indications that a digital implementation in the construction industry can generate positive effects for what currently constitutes one of the industries with the highest environmental impact.[2, 53]

4 Results

4.1 Scope 4 - Positive Impact

As found in the initial literature review, there is a lack of including any positive aspects or opportunities in the concept of *climate impact*.[32] It did not either take a long time before realizing that there is conceptual confusion in the field of positive climate assessments. This has been confirmed in recent studies, showing how there is a highly inconsistent-, and fragmented use of the terminology that many times aggravates the contextual understanding of the message for the reader. Many concepts do roughly refer to the same thing, but due to tiny differences between the otherwise largely overlapping concepts, defining each concept becomes difficult.[32, 54] This is addressed for instance by Dijkstra Silva in her recent scientific contribution to the untangling of this conceptual confusion.[32]

One of the initial key findings, which became the opening for assessing the net-positive assessments, was the roadmap provided by Digitaliseringskonsulterna in collaboration with *Fossilfritt Sverige, Färdplan för fossilfri konkurrenskraft: Digitaliseringskonsultbranschen*.[55]

Digitaliseringskonsulterna is a collaboration between 29 companies from the digitalization-consultancy sector with the shared ambition of using digital solutions to reach a sustainable and smart future. Their work is based on research that shows how digitalization can help reach climate goals by reducing energy and resource demand. The roadmap has a proactive purpose and aims to facilitate Sweden's transition to becoming climate neutral in 2045 by adopting transformative technologies and measures. It is divided into sections focused on different market participants, where one of these is devoted to encouragement to the Swedish parliament and government. Digitaliseringskonsulterna advised them to complement existing incentives for companies when reporting on their emissions according to Scope 1-3 (see section 2.1.1) with incentives for reporting on "Scope 4", or *avoided emissions*.[5] This became the eye-opener for the rest of the thesis since it was here the findings started to take place.

Scope 4 can be defined as emission reductions occurring outside of a product´s value chain or life cycle as a result of using the product.[56] In comparison to Scope 1,2 and 3 which assess emissions related to the organizations' value chain or life cycle, Scope 4 does stake one step back and focuses on emissions beyond the own organization.

The concept of Scope 4 in this thesis works as an umbrella concept for several terms. Other terms used to describe this positive climate impact are *avoided emissions*, *carbon handprint*, *comparative emissions*, and *enabling effect*. These terms seem in texts, interviews, and seminars to be used more or less synonymous, but originate from different places. With that said, a reservation is left for any inherent distinguishing feature between these which did not appear in the current research.

Scope 4 was early defined in the GHG protocol, but was therein referred to as avoided emissions. The GHG protocol's definition of the concept was "emission reductions caused indirectly by a product". The product should have an enabling effect to avoid emissions, and "allow the same function to be performed, but with significantly less, GHG-emissions generated.[56] It is not counted as valid if the company only lowers its own footprint,[54] since *"we don't want to help someone lower their emissions, but help the customer help the world lower its emissions"*.[57] It is in other words necessary to differentiate between the emissions derived from the own production system and avoided emissions.[54]

This type of net positive impact can be achieved in many different ways. It can arise from a new technology, component, process, service, or product. The vital requirement is that it should lower the emissions from another production system, which in this case can be translated to a customer or another actor that is using the climate-friendly solution.[54]

One example is how virtual meetings quickly replaced physical meetings when the Corona pandemic occurred. When the meeting participants could have their meetings from home, huge amounts of emissions derived from the previous transportation of the participants to the physical meeting could be avoided. This example is very simplified. In addition, several additional factors influence the emissions generated by a solution, but in this case, the solution provider of virtual meetings is considered to enable the avoided emissions.[56]

Requena [58] reviews 15 different "Scope 4"-frameworks against a set of criteria that she finds relevant to consider in this type of concept. These are:

- Scope of the framework
- System Boundaries
- Secondary effects
- Timeframes
- Baselines
- Geography
- Allocation
- Technology Readiness Levels
- Market share/ Market penetration [58]

Requena concludes that even though several aspects differ between the frameworks she investigates, there is still a high degree of similarity in how the methods are conducted, and in how the quantified avoided emissions should be reached. The most commonly occurring steps, can have a varied order, but be summarized as follows:

- Find the solution by defining the boundaries.
- Choose and define the baseline or BAU scenario
- Find applicable emission factors both for the solution and for the baseline.
- Assess the market share or the market penetration of the solution.
- Calculate units of product or service both for the baseline and for the solution
- Calculate emissions generated by both the solution and the baseline. This is done by multiplying the units and the emission factors.
- Remove the emissions generated by the solution from the BAU. This provides the avoided emissions generated by the implementation.
- Consider the allocations for the avoided emissions. Should they be derived from other solutions as well?[58]

A crucial point is that assessing and reporting on scope 4 can- and should not replace the assessment of the negative impact in Scope 1-3, and the purpose is not to enable companies to make claims about their positive impact without at the same being transparent with their negative impact. Scope 4 should rather be viewed as a complementary part of the traditional carbon assessment to achieve a more holistic view of the impact.[56] Another general principle that is stressed is the importance of maintaining a high level of consistency, transparency, completeness, relevance, and accuracy in the communication of the results,[56, 59] or as formulated in the handprint method, appropriateness, clarity, credibility, and transparency.[54]

4.2 Existing Frameworks - A Comparison

Among the frameworks found, some of the frameworks seemed more adapted toward the target group for this thesis. The requirements used to assess the relevance of the framework were for the framework to pass the following criteria:

- The framework should apply to consultancy companies, be capable of measuring effects from project-based services, and be compatible with the building-, and digitalization sectors. At this stage, a majority of the findings were excluded.
- The framework should be provided overviewing for free. This criterion excluded a few professional companies, which according to their websites meant that they were capable of assessing avoided emissions, but not clarifying their methods used.

- The framework should contain a method for calculations, rather than just providing guidelines in terms of suggestions on actions that have the potential to reduce emissions. Since most frameworks are developed as estimations, these criteria became a bit fluid, and depending on their inherent attitude towards levels of detail, their categorization became aggravated. Some of the frameworks considered themselves as guidelines rather than method but did in the end still generate some sort of number on the calculated emissions. Other frameworks defined themselves as methods but added that the results contain great margins of error that increase the uncertainty. In addition, some frameworks were only focused on demonstrating the potential of existing solutions and climate-efficient inventions but did not apply to companies' own innovations. Such frameworks were excluded here.

I found three frameworks that assess scope 4 that seemed to be most applicable to the target group. These are:

- *The Avoided Emission Framework (AEF)*
- *The Carbon Handprint Method*
- *Estimating and Reporting the Comparative Emissions Impacts of Products*

Table 1 summarizes some of the vital parts of each of the selected frameworks.

Name	Publisher	Release date	Target group	Applicable for	Calculation/Method
The Avoided Emission Framework	Mission Innovation	2019-11	Companies, Investors, Seekers for new solutions	Products, services, companies, cities	Compares the baseline scenario with the solution scenario but includes most additional aspects in the calculation among all the frameworks compared.
The Carbon Handprint Guide	VTT and LUT university	2018-11	Organisations and actors wanting to measure their own emissions	Raw materials, Components, Fuels, Technologies, Processes, Products and Services	LCA-based approach. Compares the baseline scenario with the solution scenario.
Estimating And Reporting the Comparative Emission Impact Of Products	World Resources Institute (WRI)	2019-03	Companies wanting to estimate and report on their comparative GHG impact	Goods and Services	LCA-based approach compares the baseline scenario with the solution scenario. Provides 2 approaches to choose between. One is simpler, covering scope 1 and 2. The other is more comprehensive, covering scope 1,2 & 3.

Table 1: Demonstrates each of the chosen framework's approaches towards chosen criteria. The content in the tables is derived from each of the original frameworks.[56, 54, 59]

4.3 The Suggested Frameworks For Digital Solutions

4.3.1 The Avoided Emission Framework

The AEF is provided by Mission innovation, a global catalyzing initiative that collaborates with several actors, both on global and national levels, such as the World bank group, World Economic Forum, International Energy Agency (IEA), etc. The AEF constitutes a crucial part of the activities derived from the Mission Innovation Action Plan for 2018-2030. The first document was published in November 2018 and has since then been updated based on input from stakeholders.[56]

The AEF aims to provide a way to assess avoided emissions to enable comparisons between different solutions based on their positive climate contribution. The framework should be applicable for both products, solutions/services, and whole companies or even cities, and the calculation consists of a comparison between the solutions emissions and a baseline which is the BAU scenario.[56]

The calculation can be simplified as in equation 1.

$$E_{\text{net avoided}} = E_{\text{enabling avoided}} - E_{\text{direct solution}} - E_{\text{rebound effect}} \tag{1}$$

where

$$\begin{aligned} E_{\text{net avoided}} &= \text{Net avoided emissions} \\ E_{\text{enabling avoided}} &= \text{Enabling avoided emissions} \\ E_{\text{direct solution}} &= \text{Direct solution emissions} \\ E_{\text{rebound effect}} &= \text{Rebound effect emissions} \end{aligned}$$

The suggested method can in short be summarised as a comparison between the emissions from the BAU baseline scenario and the emissions from the solution-enabled scenario, provided by calculating the emissions in the categories below. The given difference demonstrates the solution's capacity of reducing the overall emissions from the system.[56]

Some crucial parts to understanding the concept of avoided emissions are, therefore:

- The Solution
- The BAU system
- The enabling effect
- The direct solution emissions
- The rebound effect.[56]

The solution is a product or a service with enabling effects for avoiding emissions.

The BAU system is the emissions occurring in a scenario without introducing the enabling solution.

The enabling effect is the avoided emissions by using the solution and can be primary or secondary. Primary effects are effects directly associated with or arising by using the solution, while the secondary effects are more long-term.

The direct solution emissions are the life cycle emissions from the solutions arising from the enabling effect.

Rebound effects are increases in the BAU scenario given by the implementation of the enabling solution. The rebound effects are often related to changes in human behavior and can either be caused by related consequential-, or unrelated effects. Rebound effects are extremely hard to predict and quantify and therefore contain great uncertainty. In the case of virtual meetings, this could for instance be if more and more people started flying abroad because they suddenly had both more time and money left. The positive effect, in this case, the avoided emissions from the absentee transport to the meetings is thus fully or partially overcompensated with a rebound effect.[56]

In addition, when the approach is used for future scenarios, which most often is the case for new solutions or technologies, both the probability of successful development and the probability of chance that the solution gets adopted. Also, the volume of the solutions that are deployed is included in the calculation. Equation 2 shows the possible future impact of the solution by including the probability of success, probability of adoption, Volume, and the Carbon abatement factor.[56]

For each enabling solution, a carbon abatement factor is also decided. By deciding the carbon abatement factor, a normalized factor is provided which helps increase the comparability and consistency.[56]

$$\sum P_{\text{success}} \cdot P_{adoption} \cdot V \cdot \text{CA}_{\text{factor}} = \text{CA} \pm I \tag{2}$$

where

P_{success} = Probability of success
P_{adoption} = Probability of adoption
V = Volumes
CA_{factor} = Carbon Abatement factor
CA = Total Carbon Abatement
I = Uncertainty

4.3.2 The Carbon Handprint Guide

The Carbon handprint guide is an approach that was first launched in 2018, with a second version launched in 2021. The framework is provided by VTT Technical Research Centre of Finland Lrd and LUT University.[60]The term carbon handprint, however, was minted already in 2007 by the Centre for Environment Education, (CEE) during UNESCO's 4th International Conference on Environmental Education.[54]

The carbon handprint approach applies to processes, products, services, raw materials, components, fuels, and technologies, and has been proposed as an effective way of evaluating and communicating the beneficial environmental impacts of a given solution. The approach is suggested to fit actors with expertise in, and experience from LCAs, and the ISO 14067 standard.[54]

Both the footprint- and the handprint approach are based upon LCA assessments which can be performed against ISO 14040-44. This means that there are standardized parts included in the assessment, even though the framework itself is no exception from the other AEFs when it comes to the absence of standardization.[54]

The calculation process is a four-stage process with ten steps. The calculation is largely based on the LCA method.[54] A handprint arises either when reducing the customer's footprints by offering a solution that is so much better that it drops the footprint to a level under the BAU, or by contributing to a lowering of the customer's footprints generated through their processes. The handprint will be equal to the footprint reduction occurred by the user of the product but is derived from the solution that enables the footprint reduction.[60]

See equation 3 for how the carbon handprint is calculated.

$$\mathrm{HP}_{\text{product,service}} = \mathrm{FP}_{\text{baseline}} - \mathrm{FP}_{\text{offered solution}} \tag{3}$$

where

$\mathrm{HP}_{\text{product,service}}$ = Handprint of the offered product or service in use

$\mathrm{FP}_{\text{baseline}}$ = Footprint of the baseline

$\mathrm{FP}_{\text{offered solution}}$ = Footprint of the offered product or service in use

Applicational case

There is at least one company that has used the handprint approach for assessing its environmental performance. That is Foxway, a company working with a circular economy, and strives to help others by providing digital solutions. Foxway did 2021 develop a handprint report that "estimates the positive impact of Foxway, using the handprint approach". For Foxway, their BAU is set to be someone who buys a new laptop, and related to the calculation, the estimated time they assume that a laptop is being used is set to 3 years. Since the business concept for Foxway is to restore old laptops, and the fact that 86 % of the laptops they are using are older than 4 years, they assume to classify the reused laptops saved as disposal. By including these factors in their calculations, just one of their refurbished laptops is assessed to generate a carbon handprint consisting of 258 kg CO2-eq.[61]

4.3.3 Estimating And Reporting The Comparative Emissions Impacts Of Products

This framework is a working paper provided by WRI. WRI is a science- and evidence-based institution that since 1982 when they were founded, has worked to move human societies into long-term sustainable states. The institute consists of around 1700 employees and works with partners in more than 50 countries.[62]

The framework introduces a method that aims to help companies estimate and report on their *comparative GHG emissions impact from a solution, about a case where the solution does not exist*. The framework is based on established life-cycle accounting approaches. The framework contains two different approaches, attributional and consequential, which can be used depending on the circumstances, and which information is possible to get access to.[59]

The first one is the attributional approach, seen in equation 4, which is more simplified and only addresses scope 1 and scope 2 in terms of direct and indirect emissions. This approach generates absolute emissions and removals derived from a certain product, solution, company, or city.[59] The approach does not involve any rebound effects, changes in market share, or market size, and is suggested when the data needed for the consequential approach is not available.

$$I_{GHG} = LCE_{\text{reference product}} - LCE_{\text{assessed product}} \tag{4}$$

where

$$\begin{aligned} I_{GHG} &= \text{Comparative GHG Impact} \\ LCE_{\text{reference product}} &= \text{Life Cycle Emissions of reference product} \\ LCE_{\text{assessed product}} &= \text{Life Cycle Emissions of assessed product} \end{aligned}$$

The other more comprehensive alternative, seen in equation 5, is the consequential approach. This approach does, beyond Scope 1 and 2, also includes Scope 3. The comprehensive approach which is highly suggested to use to inform decision-makers, aims to estimate the system-wide changes in emissions and provide a result that includes more aspects related to the market effects. It builds on previously existing Consequential LCA and the GHG Protocols Policy and Action Standard. This approach is more holistic than the attributional but is also associated with a higher degree of uncertainty due to the current lack of available data and emission factors.[59]

$$I_{GHG} = E_{baseline} - E_{policy} \tag{5}$$

where

I_{GHG} = Comparative GHG Impact (Policy and Action Standard)
$E_{baseline}$ = Emissions in baseline scenario
E_{policy} = Emissions in policy scenario

4.4 Why Is Scope 4 Needed?

There are several reasons why a Scope 4 framework is desired. In this thesis, this is simplified into two sides, the solution provider's side and the stakeholder's side.

For solution providers

For companies and actors which are trying to develop and promote low-carbon solutions, there are great desires and benefits associated with being capable of demonstrating their unique benefits and informing their stakeholders in a trustful way about their positive contribution.[56, 58, 63] The consultancy industry is just one of many sectors where this is useful since a consultant's climate impact tends to occur beyond scope 3, and in the unofficial scope 4. Consultancy's projected solutions are not owned by their own company, but by their customer. In cases where these solutions are innovative and come with great climate benefits, the consultants want to be able to demonstrate what climate benefits they have achieved.[64] According to Pilborg, estimations on the environmental impact from his sector, which is ICT-consultancy, is that in general, it tends to do around 20 times more good than harm. That is why one of their greatest desires in terms of environmental assessments is an implementation of an industry standard that provides them with useful numbers on their impact that they can present to their customers.[27] Pilborgs reasoning is in line with Halvardssons's regarding the capacity of the consultancy sector, who argues that the consultancy industry holds great potential when it comes to the global sustainability transition.

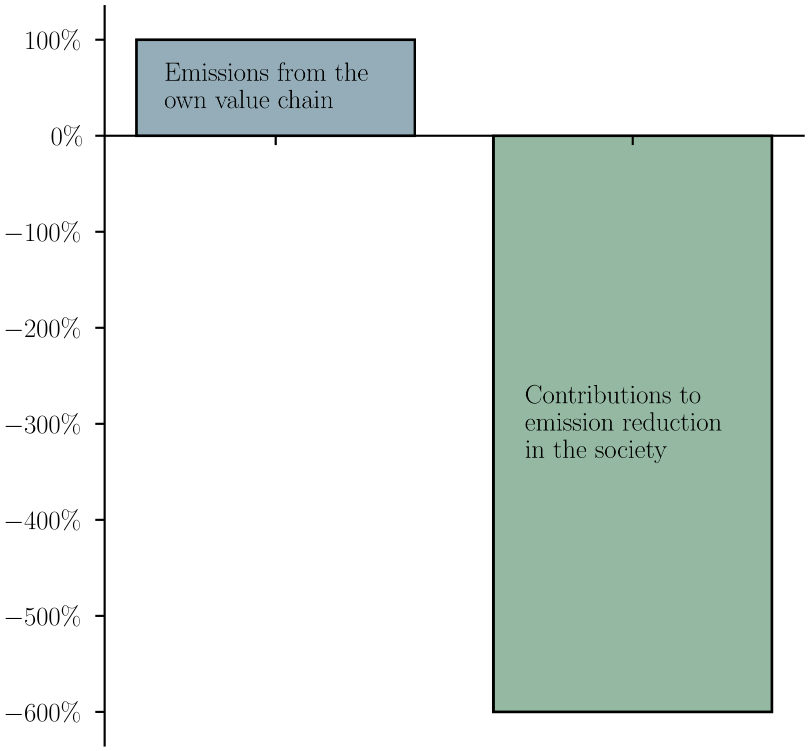

Figure 2: Illustrates the net difference between the company's own emissions and their contributions to emission reduction. Illustration inspired by Cybercom- full version Digital sustainability report 2021.[65]

> *"The common denominator of consultants is that we often help other industries to change. Despite that, consultant's climate assessments usually consist of calculating the internal energy use, employee travels, and paper prints, even though the major environmental impact occurs at the customers."*[25]

Halvardsson further argues that the consultancy sector currently is seeking support in how to calculate and assess environmental impact, and how to reach out. He mentions that a crucial part is a need of creating a debate dialogue.[25]

Although research on decarbonization and other climate efforts has been going on for a long time, there is a lack of established methods and frameworks that can capture the real effects of such efforts. Pamlin argues that for the concept of "enabling solutions" to not end up being just another buzzword, there is a need of measuring the potential and not only the burden.[66] He also states how *"most current frameworks are based on* *yesterday's world"*,[57] in a time where there is an urgent need of accelerating emission reductions.[56]

This desire of finding ways to measure and assess scope 4 is shared among several digital consultancy companies. Even though they in many ways are competitors, they all profit from fast change and do therefore share the common fear that the business would maintain a BAU scenario.[64] The industry organization *Digitaliseringskonsulterna* constitutes an illustrative example that shows the strong will that exists on the industry side. Even though Digitaliseringskonsulterna is a collaboration between competing companies, the members are so strongly agreed in their desire for this type of framework to evolve that they have started and dedicated a certain working group for assessing scope 4/avoided emissions. The working group is by the time this thesis has been conducted in the ongoing process of developing their framework which they hope will fulfill this need. According to Halvardsson, their framework highly relies upon the AEF. *"I have spent a lot of time investigating avoided emissions and scope 4, and the best outcome that I so far have got is the innovation-driven concept of avoided emissions"*.[25]

Halvardsson and Pilborg agreed that a great part of the limited dissemination for scope 4 assessment approaches lies within the lack of actual implementations. There are already companies that claim they generate avoided emissions without having used these frameworks. That is possible since one current option is to hire external specialist consultants who help them with the calculations and provide data on the avoided emissions given from running/using their product/process. Which methods that are used among companies providing this type of service have not been possible to identify, since all of the identified companies with that service were contacted without response. Hiring a company to help with the calculations is expensive, and provides the company with detailed calculations. For a company with many different solutions, a new calculation must be carried out for each solution, making this alternative expensive. In addition, the given results are many times much less useful than desired, since they lack a relevant context to be placed, to make sense, making this into an expensive and many times unuseful alternative.[27, 25] I would say that this could be compared to a situation where someone is buying an expensive phone to enable talking with others. For that extra cost to get a purpose, it requires a context where others who also phone for you to be able to talk, otherwise it doesn't matter how good or expensive your phone is.

Pilborg further explains that just as moving firms can offer free relocation offers to enable price comparisons for their customers, the desire for the consultancy industry is to be able to conduct similar assessments, based on carbon emissions. The desire is to be able to provide the customer with concrete numbers on the avoided emissions given by the impact of the solutions beforehand, to enable the customer to make comparisons between different alternatives before making their decision. For moving firms, providing a cost suggestion is possible since they have conducted enough moves to understand the workload of moving a 77-square-meter household without access to a lift. Such a context is missing for assessing avoided emissions, making current numbers less useful. In the end, it boils down to the tradeoff between the need for this service being cheap enough for the industry to provide calculations in advance to their customers, and the need for scientific adequacy and good quality of the assessment so that the customer wants to pay for it at the same time as the result becomes useful.[27]

Another tradeoff discovered with the assessments, is the one between scientific accuracy and the climate changes urgency, since waiting for the perfect solution to appear before starting to act will decrease humanity's change in combating climate change.[3] Halvardsson replies to the question of whether it is best to wait for a perfect method, or to start using a ''half-baked" one, that course it is important to have scientific accuracy and grounding in the method, but at the same time, it is important to take one step back and overview the whole. He means that it is already possible today to detect which industries have the greatest impact, and which areas consultancy could choose to work with to achieve positive climate impact. By starting working with those it is possible to make a positive difference, even without having detailed numbers on it. That means that it is possible to act in a constructive way for this sector, even before the perfect method exists.[25]

For the stakeholders

Scope 4 frameworks would also provide clear benefits for the companies' stakeholders such as customers, investors, politicians/decision makers, and governments with useful tools, such as to see through greenwashing campaigns, and understand what they are buying. The lack of ways to measure the enabling effect hinders investors from discovering and comparing truly potent, effective solutions, and risks missing important solutions which could be accelerated and upscaled to an important part that combats climate change. Having access to a Scope 4 framework would therefore likely decrease the time it takes before the right solution can reach the market. In the same way as the financial world since way back in time has been capable of calculating the expected cost of the return, there is a need to enable calculating the potential climate benefits from different solutions to predict where the investment can have the best effect in terms of benefits for the climate.[67] Successful implementation of a scope 4 framework could further be related to costs since it would enable governments to understand and see the true capacity and possible effect of different solutions, which could help to invest in technologies that could spare humanity from future climate change-related costs.[48]

In a webinar with Pamlin, a man with a clear innovative background who is one of the co-founders of the AEF, he explains that just a couple of years ago, the obvious narrative was to view companies as sources of environmental burden and guilt. The most progressive question related to companies' climate impact was thus to ask *"Who can claim that they reduce their emissions the most?"*. Pamlin is critical of this way of viewing companies, and suggests that a more constructive approach would be to ask *"who can come up with solutions?"*. That shifts the usual association between environmental impact and guilt, which frequently occurs when measuring carbon footprints, into focusing on Green revenues and opportunities.[66] Even though you don't have a huge negative impact yourself, you still have the potential to contribute to a great impact.[57]

> *"We are talking about innovations, but think incremental. We are talking about environmental labels, and ask ourselves how to improve that, rather than thinking disruptive."[66]*

Pamlin further points out how the focus needs to shift from assessing historical events to looking at future opportunities. Investors need to stop focusing on carbon exposure and the current degree of risk and start reflecting on the opportunities for coming up with solutions that rapidly can be scalable. Companies need to start questioning what their purpose beyond profit is, and what they can provide society beyond succeeding with regenerative investments and business management.[66]

Pamlin's reasoning about environmental opportunities is supported not only by the industry but is also grounded in the scientific literature, for instance by research in social cognitive neuroscience on how to conduct the most constructive sustainability management strategies.[32] To improve environmental performance, the strategy benefits largely from going through a transformative reformulation that changes the negative and guilty mindset to positively viewing the efforts as a good contribution.[60, 32]

4.5 General Challenges For The Frameworks

Much of the challenges with the Scope 4 frameworks are derived from the intrinsic, interacting networks of factors that affect multi-disciplinary problems on large scales. Many of these, such as the challenges in deciding scopes, setting up a baseline scenario, and temporal and spatial boundaries are addressed by Requena, in her already-mentioned compilation of existing frameworks.[57]

Further, the fact that these types of frameworks are predictive rather than historical is another great challenge, not least when it comes to forecasting complex networks of causes and effects, such as for the societies in which the assessed solutions operate.[56] In theory, when isolating a single solution, it might not be as complicated to understand and determine its impact. In practice, however, no one of the solutions operates in a vacuum, making it necessary to anticipate future domino effects, as well as decide which of these effects to include and which to ignore.[33]

In order just to set up a baseline, or decide the solutions scenario, there is a need of understanding both the direct and indirect effects generated. Direct effects tend to be easier to decide than indirect effects, but at the same time, many times constitute a much smaller part of the total impact.[68] Understanding the effects of digital solutions is a good and relevant example of some of the challenges.[3] First, when it comes to new technologies there is a lack of insights about their true effects which complicates the assessment. Secondly, many digital implementations do not operate independently of each other, but rather as integrated parts in systems, making their interaction and compatible ability crucial to consider. This tendency of digital transformations to rely on external factors makes solutions more sensible for differences within different industries, contexts, and geographical locations, making it difficult to get a generalized evaluation that can be used in a method applicable to many types of businesses.[69]

Due to IPCC, it is crucial to careful societal coordination of digital technologies, since they otherwise risk increasing the net-energy use because of the energy needed for each device.[3] Technologies associated with digitalization tend to have a high direct environmental impact per device related to their resource requirements during the production phase, but also during their life cycles. The lifetime is many times shorter than for their analog precursor, and the disposal process is rarely capable of handling the devices properly, resulting in e-waste and hazardous waste. Some of these aspects, such as improving the waste management processes, and minimizing the emissions generated in the production, due to streamlining effects, are processes that can be solved by digital solutions such as AI,[46] but how much the enabling effects can compensate for the problematic aspects is still the question desired to be preserved.[70]

Further, since the currently existing methods for deciding the positive environmental impact relies upon many of the same principles as the ”traditional” methods that assess the carbon footprint, the same challenges exist for deciding to avoid emissions. According to Bastviken *”there are available ways to measure carbon emissions, which theoretically are capable of providing great results, with sufficient access to funding and time and know-how for troubleshooting and adaptions to the local conditions.”*. The problems with these methods arise when attempting to translate these to the industry.[28]

A great and overarching challenge for the assessments is in other words the lack of data, a challenge which is not unique to assessing the climate but also highly affects most environmental- and sustainability measurements.[9, 71, 72] Bastviken, in his article, shows that the lack of data highly affects the current methods for carbon assessments,[9] and explains that as long as representative data on the emissions do not exist, it doesn’t matter what method is used. He compares it with a house of cards when he explains that the foundation must be correct for the rest to hold since *”the assessments are only as good as the quality of the input data”*.[28] Bastviken also suggests that the main bottleneck, in this case, is the measurement techniques, and the fact that current sensors used in the industry are of too low quality, and cannot capture all the information that is needed. The techniques at present are both too expensive, and can not generate proper, representative data, which is needed for the framework’s results to be reliable.[28]

5 Discussion

What has been found during this research is that there are several concepts used for describing the positive effect generated by digitalization consultancy companies' improvements on their customers' climate impact. The main terms used seem to be *Scope 4*, *Avoided emissions*, *Carbon handprint*, *Comparative emissions*, and *Enabling effect*, concepts which refer to the positive effect given by using a solution that lowers the generated emissions in comparison to a BAU scenario. To consider a company's avoided emissions beyond assessing Scope 1, 2, and 3 is important since it provides a more holistic approach toward climate impact. A societal adaptation of using Scope 4 would provide stakeholders and investors with a new, more sustainable measure to use when comparing new potential investments, products, or solutions. Rather than just considering the price tag, it would become possible to make decisions based on the solution´s enabling effect, something which is important in a time when climate change is more urgent than ever before.

There are several more or less developed frameworks and methods available for companies that want to measure their positive climate impact. Many of these have several similar characteristics in their design and function, but differ in which areas they include in the assessment, and how comprehensive they are.[56] The frameworks which seemed to be most applicable for a consultancy company like Plan B were the *Avoided Emission Framework*, *The Carbon Handprint method*, and *Estimating And Reporting The Comparative Emission Impact Of Products*. All three selected frameworks are based upon the same idea of comparing a baseline scenario with a solution scenario to determine the enabling effect from the assessed solution. The main difference among the frameworks is how these scenarios are decided, and which aspects are involved when deciding them. The baseline is a vital part to find out whether any reductions occur, and to be able to define the generated impact as a reduction[56] since it is by comparing the baseline with the impact of the solution that the reduction could be found. For digitalization consultancy companies, operating in the societal building industry this becomes problematic, due to the lack of homogeneity between projects which makes the baseline constantly changing. Plan B has projects both in hospitals and universities, as well as airports and water treatment plants.[73] The high variation between who their customers are, and the customer's demands, means that for Plan B to determine a baseline for a BAU, a parallel projection should be needed. Today, that would not only be practically difficult but also probably outweigh the expected positive climate impact of the climate-efficient solution. The challenge of defining the baseline does therefore complicate a potential adaptation of any of the proposed frameworks at the current state.

Another shared aspect among the frameworks is their attitude toward transparency, clarity, and consistency,[56, 60, 59] things that can be difficult to control by external means, but that should characterize the ethical attitude of the actor that is considering to use of any of these positive frameworks.

If looking beyond those challenges, the AEF seems to be the most suitable and useful framework due to its holistic design and inclusion of multiple factors beyond the more traditionally used baseline and solution scenario. This is in line with previous investigations, as well as results provided by interviewees.[25, 58] Both the Carbon handprint method, and Estimating and reporting the comparative emission impact of products are LCA-based, and not as comprehensive as AEF. Results provided from an LCA-based framework are probably more contextually dependent, and therefore possibly more suitable for product-based industries with more standardized processes, even though both frameworks state that they are applicable for services and processes as well. For a project-based and highly transformative business such as Plan B, an LCA-based approach probably would not capture as many of the relevant factors for the result as the AEF. On the other hand, it is also possible to argue that since the AEF contains more factors and aspects, there is a higher need of finding data and making assumptions, which also complicates the assessment.

This ties into the opportunities for digitalization. Digital implementation currently occurs at a fast pace all around society in line with industry 4.0,[69] and digital implementation is the single most monumental change for the building-and construction sector. Digital technologies can not only increase overall efficiency by integrating intelligent features, but also simplify and enable involved actors in the construction process to constantly have access to information exchange.[44]

Even though there is much scientific evidence for positive climate effects generated by digital implementations, it is currently hard to decide the specific quantified numbers on the generated effects from the industry side. This depends on several factors, not least the data, which currently is of too low quality, and is too fragmented to make doubtless conclusions on it.[44, 69, 28] The data quality can be increased by increasing the capacity of the data-collecting mechanism. Bastviken argues that the quality of the sensors most commonly used in industry is too low for generating real results. That is because the high-quality sensors, which can be found in a research project with sufficient access to funding, currently are too costly for many industries to implement. This constitutes a bottleneck that needs to be improved to enable more realistic assessments of the climate impact from what is being assessed.[28]

Thus, it seems like the question of how data on digital technologies could be collected answers itself. Many of the high-tech digital solutions provided in the industry today, such as digital twins, are based upon real-time communication, which requires information in terms of data to be able to make real-time decisions. Improvements in these technologies will probably improve the overall capacity of collecting data that is needed also for the assessments, which means that in parallel to the new technological advances made, more detailed data will likely be collected. That would mean that much of the data needed, which currently is lacking for the results to be useful, probably will arise from digital technological advancements in the future.

A final reflection is thus that since many initiatives, frameworks, and articles found were published during the past 4 years, more and more spotlights seem to be directed toward this way of assessing the climate impact from a more holistic approach. This implies that maybe we currently are about to be facing the tip of an iceberg, and that the scope 4 concept soon might be a widespread term.

5.1 Confusion Of Concepts And Terminology

A great challenge when writing this thesis has been large fragmentation in the use of concepts, which confuses and complicates the understanding and the search for relevant findings.[32] A personal belief why the situation looks like that is because the same terms are used for describing such a high variety of things, referring both to similar- and opposite phenomena. For instance, the commonly described act of *measuring climate impact*, has been found to refer both to positive, negative, direct and-/or indirect impact, The context, which is of high relevance to understanding what is meant is often in-explicit, and it feels like there are too many different needs that claim using a vocabulary which no longer accommodates all the claims. Many concepts referring to positive climate measures get milked and lose their original function when being overused or misused, aggravating the communication for actors who want to and master to apply the terms correctly.

5.2 Limitations And Improvements

Writing this thesis has been a motley way that has involved several perspectives from many different areas.

Even though the number of actors working for increasing sustainability in the building- and construction sectors is high, it is hard to get a hold of information regarding their environmental assessments. Both in terms of scientific literature, as well as from industry. Much of the available information has to a large extent been fragmented into bits and pieces, and in many cases far from easy to translate to the relevant area. This conceptual confusion, in combination with the existing lack and challenges for current measurement methods, accommodates opportunities for greenwashing and exaggerated positive calculations. This motivates the need for maintaining or even improvement of the degree of company transparency.

During the conduction of the thesis, several persons and actors of relevance have been contacted without response resulting in knowledge gaps that have been left unanswered. At the same time, this rate of non-response could if interpreted as a result of uncertainty, possibly be considered as a strengthening argument that there is a lack of information and knowledge about the subject.

The digital landscape is rapidly changing, and what is considered relevant today, might therefore be irrelevant tomorrow, making the results a snapshot of the current state rather than objective truth. For the frameworks, what constitutes a solution today, will likely in many cases sooner or later become the baseline, making it important to continuously evaluate the relevance of the assumptions made. This rate of change can however also be connected to the choice of method. Santana Points out that qualitative research methods in some cases contain shortages associated with validity and replicability,[22] and in this case, the high rate of change in the field might affect the relevance of the results generated by this form of semi-structured qualitative study more than if the results would have been quantitative. On the other hand, only using quantitative methods would not have been enough to collect the insights made during this thesis. A combination of qualitative and quantitative methods, for instance, testing to apply the frameworks at Plan B, would possibly have increased the replicability and validity of the results but has not been accommodated in this study. This, therefore, constitutes a further research proposal.

6 Conclusions

There is a strong will, ambition, and capacity on the industry side when it comes to combating climate change. There is much that can be done, and also available ways existing and are under development, that strive to facilitate the capacity in the right direction, transforming it into actions.

The concept of climate impact is not static and is currently under transformation. For a long time, actors have studied how they can do less bad by focusing on reducing their emissions, but innovative more holistic ways of viewing environmental impact looking beyond the company's boundaries to see what more can be done for the climate. This arouses interest among companies and investors to find ways to measure these enabling grants that mean opportunities rather than burdens. Measuring and demonstrating one's avoided emissions both constitute a sale argument, but does also help investors find forward-looking companies to invest in, to accelerate the urgent strategies for beating climate change.

Currently, there are available frameworks and alternatives which in theory can quantify avoided emissions, but the relevance of the outcome is uncertain since the practical applications encounter several challenges associated for instance with the data availability and the data quality. It is difficult to predict the future, giving the frameworks and their provided results an inherent uncertainty, and challenges in how they should be interpreted.

Personally, I believe that there is a lot to win for companies in continuing to explore the area of avoided emissions. Adopting a transparent approach, keep trying out existing methods, and showing one's will are efforts that can constitute important steps in the continued development of the frameworks.

Appendices

G Appendix A

G.1 Scopus

Scopus	Hits
Consultancy + Environmental + assessment	166
Consultancy + Environmental + Measure	62
Consultancy + Environmental impact + Measure	27
Consultancy + Climate impact + Scopes	1
Consultancy + Environmental Impact + Scopes	7
Consultant + Company + Environmental + Impact + Measure	24
Consultant + Company + Environmental + Impact + Scopes	10
Consultant + Company + Environmental + Impact + Report	17
Consultant + Company + Environmental + Impact + Accounting	6
Consultant + Company + Environmental + Reporting	24
Project + Based + Industry + Environmental + Reporting	101
Project + Based + Industry + Environmental + Rreporting + Measure	22
Project + Based + Industry + Environmental + Accounting + Measuring	6
ESG + Environment + Iindicators	47
ESG + Environment + measure	72
ESG + Environment + quality	50
ESG + Environment + Rerformance	238
ESG + Environment + Performance + Standard	22
ESG + CEP	2
Project + Based + Industry + Environment + Enabling + Effect	35
Consultant + Company + Environment + Enabling + Effect	1
Consultancy + Measure + Enabling + Effect	3
Environmental + Enabling + Effect + Digitalization	12
Environmental + Added + Value + Digitalization	18

Table 2: Scopus hits, 1st part

Scopus	**Hits**
Environmental + Abatement + Digitalization	5
Environmental + Digitalization + Added + Value + Measure	2
Environmental + Climatechange + measure	6614
Environment + measure + company + how	6614
Environmental + Impact + Measure + Company	2059
Decide + Environmental + Impact + Company + How	98
Calculate + Climate + Impact	2348
Calculate + Environmental + Impact	5285
Environmental + assessment + method	121554
Measure + climate impact + method	4090
Climate + impact + tool + measure	1765
Climate + impact + tool + measure + companies	53

Table 3: Scopus hits, 2nd part

G.2 Web of Science

Web of Science	Hits
Consultancy + Environmental + Assessment	780
Consultancy + Environmental + Measure	540
Consultancy + Environmental + Assessment + Measure	125
Consultancy + Environmental + Impact + Measure	154
Consultancy + Environmental + Impact + Measure + How	25
Consultancy + Climate + Impact + Scopes	6
Consultant + Company + Environmental + Impact + Measure	35
Consultant + Company + Environmental + Impact + Scopes	5
Consultant + Company + Environmental + Impact + Report	43
Consultant + Company + Environmental + Impact + Accounting	20
Project + Based + Industry + Environmental + Reporting	2757
Project-based + Industry + Environmental + Reporting + Measure	2
Project-based + Industry + Environmental + Accounting + Measure	3
Project-based + Industry + Environmental + Enabling + Effect	4
Consultant + Company + Environmental + Enabling + Effect	5
Consultancy + Measure + Enabling + Effect	49
Environmental + Enabling + Effect + Digitalization	29
Environmental + Added + Value + Digitalization	30
Environmental + Abatement + Digitalization	5
Environmental + Digitalization + Added + Value + Measure	4
Sustainability reporting	3
Sustainability reporting + Content	2761
Sustainability + Concept + Involves	2673
Project-based + Industry + Environmental + Reporting	23
ESG + Measuring, + Companies	192
ESG + Methods + Measure + Companies	32
ESG + Environment + Variable + Measure	15

Table 4: Web of Science hits, 1st part

Web of Science	**Hits**
ESG + Environment + Measurement	16
ESG + Environment + Indicators	38
CEP + Environment + Indicators	12
CEP + Measurement + Method	166
CEP + Measurement + Enabling	29
CEP + Framework + Enabling	45
CEP + Framework + Environment	42

Table 5: Web of Science hits, 2nd part

G.3 Science Direct

Science Direct	Hits
Consultancy + Environmental + Assessment	11500
Consultancy + Environmental + Impact + Measure	10356
Consultancy + Environmental + Assessment + Measure	9575
Consultancy + Environmental + Impact + Assessment + Measure	7283
Consultancy + Environmental + Impact + Assessment + Measure + Digitalization	1398
Consultancy + Environmental + Impact + Measure + Digitalization + Enabling	867
Consultancy + Environmental + Impact + Scopes + Digitalization + Enabling	702
Consultancy + How + Environmental + Measure + Impact + Digitalization	2033
Project-based + How + Environmental + Measure + Impact + Digitalization	62100
Project-based + How + Environmental + Measure + Impact + Framework + Digitalization + Enabling	10177
Project-based + How + Environmental + Measure + Impact + Framework + Digitalization + Carbon + Abatement	725
Measure + Impact + Framework + Digitalization + Carbon + Enable + Abatement	628
Framework + Assessing + Effects + Digitalization + Carbon + Enable + Abatement	511
Framework + Digitalization + Carbon + Avoided + Emission + Services	6159
ESG + Measuring + Companies	1960
ESG + Methods + Measure + Companies	1596
ESG + Environment + Variable + Measure	1676
CEP + Environment + Indicators	5398
CEP + Environment + Measure + Method	10749

Table 6: Science Direct hits

References

[1] Schaltegger S, Csutora M. Carbon accounting for sustainability and management. Status quo and challenges. Journal of Cleaner Production. 2012;36:1-16.

[2] Yan J, et al. Digital tools for revealing and reducing carbon footprint in infrastructure, building and city scopes. MDPI. 2022:19.

[3] Arias PA, Bellouin N, Jones RG, Naik V, Plattner GK, Rogelj J, et al.. IPCC, Technical Summary; 2022.

[4] Sweden Green Building Council. Vad är EU:s gröna taxonomi?;. Accessed: 2022-11-30. Available from: https://www.sgbc.se/utveckling/eu-taxonomin/vad-ar-eus-grona-taxonomi/.

[5] Fossilfritt sverige and Digitaliseringskonsulterna. Färdplan för fossilfri konkurrenskraft; 2019. Accessed: 2022-10-10. Available from: https://fossilfrittsverige.se/wp-content/uploads/2020/10/digitaliserings-konsultbranschen.pdf.

[6] Zhang H. Pathways to carbon neutrality in major exporting countries: the threshold effect of digital transition. Environmental Science and Pollution Research. Place: Heidelberg Publisher: Springer Heidelberg WOS:000847626600015. Available from: http://www.webofscience.com/api/gateway?GWVersion=2&SrcAuth=DOISource&SrcApp=WOS&KeyAID=10.1007%2Fs11356-022-22592-x&DestApp=DOI&SrcAppSID=EUW1ED0C10gyLSCfu5H1paVmjdPMY&SrcJTitle=ENVIRONMENTAL+SCIENCE+AND+POLLUTION+RESEARCH&DestDOIRegistrantName=Springer-Verlag.

[7] Franco JAB, Domingues AM, Africano NA, Deus RM, Battistelle RAG. Sustainability in the Civil Construction Sector Supported by Industry 4.0 Technologies: Challenges and Opportunities. Infrastructures. 2022;7(3).

[8] Bogue R. What are the prospects for robots in the construction industry? Industrial Robot: An International Journal. 2017 Jan;45(1):1-6. Publisher: Emerald Publishing Limited. Available from: https://doi.org/10.1108/IR-11-2017-0194.

[9] Bastviken D, Wilk J, Duc NT, Gålfalk M, Karlson M, Neset TS, et al. Critical method needs in measuring greenhouse gas fluxes. Environmental Research Letters. 2022 Sep;17(10):104009. Publisher: IOP Publishing. Available from: https://dx.doi.org/10.1088/1748-9326/ac8fa9.

[10] Wegener M, Labelle R, Jerman L. Unpacking carbon accounting numbers: A study of the commensurability and comparability of corporate greenhouse gas emission disclosures. Journal of Cleaner Production. 2019 Feb;211:652-

64. Available from: https://www.sciencedirect.com/science/article/pii/S0959652618335595.

[11] Hamilton SN, Waters RD. Mainstreaming Standardized Sustainability Reporting: Comparing Fortune 50 Corporations' and U.S. News & World Report's Top 50 Global Universities' Sustainability Reports. Sustainability. 2022 Jan;14(6):3442. Number: 6 Publisher: Multidisciplinary Digital Publishing Institute. Available from: https://www.mdpi.com/2071-1050/14/6/3442.

[12] Gibbssons M, Limoges C, Nowoeny H, Schwartzman S, Scott P, Trow M. The new production of knowledge: The dynamics of science and research in contemporary societies. SAGE publications Ltd; 2020.

[13] Johannisson B, Ewa G. Gemensamt kunskapsskapande-den interaktiva forskningens praktik. Växjö: Växjö University Press; 2008. 978-91-7636-621-9. Available from: http://www.diva-portal.org/smash/get/diva2:206371/FULLTEXT01.pdf.

[14] Schipper ELF, Dubash NK, Mulugetta Y. Climate change research and the search for solutions: rethinking interdisciplinarity. Climatic Change. 2021 Oct;168(3):18. Available from: https://doi.org/10.1007/s10584-021-03237-3.

[15] Bresnen M, Burrell G. Journals à la mode? Twenty years of living alongside Mode 2 and the new production of knowledge. Organization. 2013 Jan;20(1):25-37. Publisher: SAGE Publications Ltd. Available from: https://doi.org/10.1177/1350508412460992.

[16] PlanB. Om oss; 2022. Available from: https://planbab.se/om-oss/.

[17] Chiarini L, Khedachi N. Sustainability reporting in project-based industries: a European study with a focus on the motion picture industry. Malmö universitet/Kultur och samhälle; 2019. Available from: http://urn.kb.se/resolve?urn=urn:nbn:se:mau:diva-23260.

[18] Stock P, Burton RJF. Defining Terms for Integrated (Multi-Inter-Trans-Disciplinary) Sustainability Research. Sustainability. 2011 Aug;3(8):1090-113. Number: 8 Publisher: Molecular Diversity Preservation International. Available from: https://www.mdpi.com/2071-1050/3/8/1090.

[19] Roudgarmi P. Qualitative research for environmental sciences: A review. Journal of Food, Agriculture and Environment. 2011 Jul;9:871-9.

[20] Kte'pi B. environmental science. Encyclopedia Britannica. 2022 Dec. Accessed 1 January, 2023. Available from: https://www.britannica.com/science/environmental-science.

[21] Pellegrino M, Musy M. Seven questions around interdisciplinarity in energy research. Energy Research & Social Science. 2017 Oct;32:1-12. Available from: https://www.sciencedirect.com/science/article/pii/S221462961730230X.

[22] Santana FN, Hammond Wagner C, Berlin Rubin N, Bloomfield LSP, Bower ER, Fischer SL, et al. A path forward for qualitative research on sustainability in the COVID-19 pandemic. Sustainability Science. 2021 May;16(3):1061-7. Available from: https://doi.org/10.1007/s11625-020-00894-8.

[23] Brown PA. A review of the Literature on Case Study Research; 2008. Available from: https://journalhosting.ucalgary.ca/index.php/cjnse/article/view/30395.

[24] Braig P, Edinger-Schons LM. From Purpose to Impact - An Investigation of the Application of Impact Measurement and Valuation Methods for Quantifying Environmental and Social Impacts of Businesses. Sustainable Production and Consumption. 2020 Jul;23:189-97. Available from: https://www.sciencedirect.com/science/article/pii/S2352550919300466.

[25] Halvardsson P; 2022. Digitaliseringskonsulterna.

[26] Morfeldt J. Interview; 2022.

[27] Pilborg J. Interview; 2022.

[28] Bastviken D. Interview; 2022.

[29] Pamlin D. About;. Available from: https://www.pamlin.net/about.

[30] Johnston MP. Secondary Data Analysis: A Method of which the Time Has Come. Qualitative and Quantitative Methods in Libraries. 2017 May;3(3):619-26. Number: 3. Available from: http://www.qqml-journal.net/index.php/qqml/article/view/169.

[31] Snyder H. Literature review as a research methodology: An overview and guidelines. Journal of Business Research. 2019 Nov;104:333-9. Available from: https://www.sciencedirect.com/science/article/pii/S0148296319304564.

[32] Dijkstra-Silva S, Schaltegger S, Beske-Janssen P. Understanding positive contributions to sustainability. A systematic review. Journal of Environmental Management. 2022 Oct;320:115802. Available from: https://www.sciencedirect.com/science/article/pii/S0301479722013755.

[33] Harangozo G, Szigeti C. Corporate carbon footprint analysis in practice – With a special focus on validity and reliability issues. Journal of Cleaner Production.

2017 Nov;167:1177-83. Available from: https://www.sciencedirect.com/science/article/pii/S0959652617316931.

[34] Pandey D, Agrawal M, Pandey JS. Carbon footprint: Current methods of estimation. Environmental Monitoring and Assessment. 2011;178(1-4):135-60.

[35] Yan J, Lu Q, Tang J, Chen L, Hong J, Broyd T. Digital Tools for Revealing and Reducing Carbon Footprint in Infrastructure, Building, and City Scopes. Buildings. 2022 Aug;12(8):1097. Number: 8 Publisher: Multidisciplinary Digital Publishing Institute. Available from: https://www.mdpi.com/2075-5309/12/8/1097.

[36] Feng H, Zhao J, Zhang H, Zhu S, Li D, Thurairajah N. Uncertainties in whole-building life cycle assessment: A systematic review. Journal of Building Engineering. 2022 Jun;50:104191. Available from: https://www.sciencedirect.com/science/article/pii/S2352710222002042.

[37] Scrucca F, Barberio G, Fantin V, Porta PL, Barbanera M. Carbon Footprint: Concept, Methodology and Calculation. Environmental Footprints and Eco-Design of Products and Processes. 2021:1-31.

[38] Marimon F, Llach J, Bernardo M. Comparative analysis of diffusion of the ISO 14001 standard by sector of activity. Journal of Cleaner Production. 2011 Oct;19(15):1734-44. Available from: https://www.sciencedirect.com/science/article/pii/S0959652611001958.

[39] Feng H, Hewage K, Sadiq R. Exploring the current challenges and emerging approaches in whole building life cycle assessment. Canadian Journal of Civil Engineering. 2021 Apr;49. Available from: https://www.researchgate.net/publication/350744087_Exploring_the_current_challenges_and_emerging_approaches_in_whole_building_life_cycle_assessment.

[40] Ammenberg J. Miljömanagement, Miljö- och hållbarhetsarbete i företag och andra organisationer. 2nd ed. 2012: Studentlitteratur AB; 2012.

[41] Kareiva PM, McNally BW, McCormick S, Miller T, Ruckelshaus M. Improving global environmental management with standard corporate reporting. Proceedings of the National Academy of Sciences. 2015 Jun;112(24):7375-82. Publisher: Proceedings of the National Academy of Sciences. Available from: https://www.pnas.org/doi/10.1073/pnas.1408120111.

[42] Marquardt K, Olaru M, Arp AK. Study on European funding programmes for sustainable development; 2019. .

[43] Sezer AA, Thunberg M, Wernicke B. Digitalization Index: Developing a Model for Assessing the Degree of Digitalization of Construction Projects. Journal of Construction Engineering and Management. 2021

Oct;147(10):04021119. Place: Reston Publisher: Asce-Amer Soc Civil Engineers WOS:000686134900014. Available from: http://www.webofscience.com/api/gateway?GWVersion=2&SrcAuth=DynamicDOIArticle&SrcApp=WOS&KeyAID=10.1061%2F%28ASCE%29CO.1943-7862.0002145&DestApp=DOI&SrcAppSID=EUW1ED0C53ElSpvTr6VFV2DhdS3ix&SrcJTitle=JOURNAL+OF+CONSTRUCTION+ENGINEERING+AND+MANAGEMENT&DestDOIRegistrantName=American+Society+of+Civil+Engineers.

[44] Andersson N, Lessing J. The Interface between Industrialized and Project Based Construction. Procedia Engineering. 2017 Jan;196:220-7. Available from: https://www.sciencedirect.com/science/article/pii/S1877705817330527.

[45] Braz Vieira ND, Horta Nogueira LA, Haddad J. An assessment of CO2 emissions avoided by energy-efficiency programs: A general methodology and a case study in Brazil. Energy. 2018 Jan;142:702-15. Place: Oxford Publisher: Pergamon-Elsevier Science Ltd WOS:000424854900060. Available from: http://www.webofscience.com/api/gateway?GWVersion=2&SrcAuth=DOISource&SrcApp=WOS&KeyAID=10.1016%2Fj.energy.2017.10.072&DestApp=DOI&SrcAppSID=EUW1ED0D2EZhnhGguo63LWewoB28e&SrcJTitle=ENERGY&DestDOIRegistrantName=Elsevier.

[46] Dwivedi YK, Hughes L, Kar AK, Baabdullah AM, Grover P, Abbas R, et al. Climate change and COP26: Are digital technologies and information management part of the problem or the solution? An editorial reflection and call to action. International Journal of Information Management. 2022 Apr;63:102456. Available from: https://www.sciencedirect.com/science/article/pii/S0268401221001493.

[47] Çetin S, Gruis V, Straub A. Digitalization for a circular economy in the building industry: Multiple-case study of Dutch social housing organizations. Resources, Conservation & Recycling Advances. 2022 Nov;15:200110. Available from: https://www.sciencedirect.com/science/article/pii/S2667378922000475.

[48] Howard A, Tang M, Ping Yee L, Teo R, De Rui W. A framework for Avoided Emissions analysis; 2021. Accessed: 2023-01-01. https://www.schroders.com/en-lu/lu/professional/insights/a-framework-for-avoided-emissions-analysis/.

[49] Baduge SK, Thilakarathna S, Perera JS, Arashpour M, Sharafi P, Teodosio B, et al. Artificial intelligence and smart vision for building and construction 4.0: Machine and deep learning methods and applications. Automation in Construction. 2022 Sep;141:104440. Available from: https://www.sciencedirect.com/science/article/pii/S0926580522003132.

[50] Liu Z. National carbon emissions from the industry process: Production of glass, soda ash, ammonia, calcium carbide and alumina. Applied Energy. 2016 Mar;166:239-44. Available from: https://www.sciencedirect.com/science/article/pii/S0306261915014464.

[51] Yang B, Lv Z, Wang F. Digital Twins for Intelligent Green Buildings. Buildings. 2022 Jun;12(6):856. Available from: https://www.mdpi.com/2075-5309/12/6/856.

[52] Çetin S, Gruis V, Straub A. Digitalization for a circular economy in the building industry: Multiple-case study of Dutch social housing organizations. Resources, Conservation & Recycling Advances. 2022 Nov;15:200110. Available from: https://www.sciencedirect.com/science/article/pii/S2667378922000475.

[53] Xu Q, Zhong M, Li X. How does digitalization affect energy? International evidence. Energy Economics. 2022 Mar;107:105879. Place: Amsterdam Publisher: Elsevier WOS:000759016800012. Available from: http://www.webofscience.com/api/gateway?GWVersion=2&SrcAuth=DOISource&SrcApp=WOS&KeyAID=10.1016%2Fj.eneco.2022.105879&DestApp=DOI&SrcAppSID=EUW1ED0D2EZhnhGguo63LWewoB28e&SrcJTitle=ENERGY+ECONOMICS&DestDOIRegistrantName=Elsevier.

[54] Grönman K, Pajula T, Sillman J, Leino M, Vatanen S, Kasurinen H, et al. Carbon handprint – An approach to assess the positive climate impacts of products demonstrated via renewable diesel case. Journal of Cleaner Production. 2019 Jan;206:1059-72. Available from: AEF.

[55] Fossilfritt sverige and Digitaliseringskonsulterna. Om Fossilfritt Sverige; 2022. Accessed: 2022-10-11. Available from: https://fossilfrittsverige.se/vilka-vi-ar/.

[56] Stephens A, Thieme V. The Avoided emissions framework, (AEF); 2020. Available from: https://www.misolutionframework.net/pdf/Net-Zero_Innovation_Module_2-The_Avoided_Emissions_Framework_(AEF)-v2.pdf.

[57] Pamlin D. More sustainable solutions from digital technologies, seminar with Dennis Pamlin; 2019. Available from: https://www.youtube.com/watch?v=BY9TmOUhHKM.

[58] Requena A. Analysis on Avoided Emissions Frameworks. Cleantech Scandinavia; 2021.

[59] Russell S. Estimating and reporting the comparative emissions impacts of products. World Resources Institute;

2019. Available from: https://www.wri.org/research/estimating-and-reporting-comparative-emissions-impacts-products.

[60] Pajula T, Vatanen S, Behm K, Grönman K, Lakanen L, Kasurinen H, et al. Carbon handprint guide: V. 2.0 Applicable for environmental handprint. Finland: VTT Technical Research Centre of Finland; 2021.

[61] Foxway. Giving new life to old laptops: Estimating the positive impact of Foxway using the handprint approach; 2021. Available from: https://www.foxway.com/wp-content/uploads/2021/06/foxway-handprint-report-laptop-eng.pdf.

[62] World Resources Institute. About Us; 2022. Accessed: 2022-10-11. Available from: https://www.wri.org/about.

[63] GeSI. GeSI facilitates real world solutions to real world issues within the ICT industry and the greater sustainability community.; 2022. Available from: https://gesi.org/about.

[64] Goldmann M. Konsulten som hållbarhetsagent-med Mattias Goldmann, hållbarhetschef på Sweco;. Available from: https://soundcloud.com/user-714233895/43-konsulten-som-hallbarhetsagent-med-mattias-goldmann-hallbarhetschef-pa-sw

[65] Cybercom. Digital Sustainability Global sustainability as a driver of innovation and growth;. Accessed: 2022-11-16. Available from: https://static1.squarespace.com/static/59dc930532601e9d148e3c25/t/5a2c97b5e4966be66fae2716/1512871882345/Cybercom-Digital-Sustianability-full+report.pdf.

[66] Ignite Sweden. Keynote - Dennis Pamlin (RISE) & Sasan Shaba (Energimyndigheten) - Ignite Sweden Day 2019; 2020. Available from: https://www.youtube.com/watch?v=jHcEWy4aaUw.

[67] Stubelius A. Nytt ramverk ger nya perspektiv på klimatfrågan; 2020. Available from: http://www.energimyndigheten.se/nyhetsarkiv/2020/nytt-ramverk-ger-nya-perspektiv-pa-klimatfragan/.

[68] Bieser JCT, Hilty LM. An Approach to Assess Indirect Environmental Effects of Digitalization Based on a Time-Use Perspective. In: Bungartz HJ, Kranzlmuller D, Weinberg V, Weismuller J, Wohlgemuth V, editors. Advances and New Trends in Environmental Informatics: Managing Disruption, Big Data and Open Science. Cham: Springer International Publishing Ag; 2018. p. 67-78. ISSN: 2196-8705 WOS:000821148200005. Available from: http://www.webofscience.com/api/gateway?GWVersion=2&SrcAuth=DynamicDOIConfProc&

SrcApp=WOS&KeyAID=10.1007%2F978-3-319-99654-7_5&DestApp=DOI&SrcAppSID=EUW1ED0F44jsXvHXHCrhJBRB8eO1J&SrcJTitle=ADVANCES+AND+NEW+TRENDS+IN+ENVIRONMENTAL+INFORMATICS%3A+MANAGING+DISRUPTION%2C+BIG+DATA+AND+OPEN+SCIENCE&DestDOIRegistrantName=Springer-Verlag.

[69] Bai C, Dallasega P, Orzes G, Sarkis J. Industry 4.0 technologies assessment: A sustainability perspective. International Journal of Production Economics. 2020 Nov;229:107776. Available from: https://www.sciencedirect.com/science/article/pii/S0925527320301559.

[70] Castro GDR, Fernandez MCG, Colsa AU. Unleashing the convergence amid digitalization and sustainability towards pursuing the Sustainable Development Goals (SDGs): A holistic review. Journal of Cleaner Production. 2021 Jan;280:122204. Patent Number: 1 Place: Oxford Publisher: Elsevier Sci Ltd WOS:000612538300018. Available from: http://www.webofscience.com/api/gateway?GWVersion=2&SrcAuth=DynamicDOIArticle&SrcApp=WOS&KeyAID=10.1016%2Fj.jclepro.2020.122204&DestApp=DOI&SrcAppSID=EUW1ED0EC5MsUBgnLP6yOq8XVWpfc&SrcJTitle=JOURNAL+OF+CLEANER+PRODUCTION&DestDOIRegistrantName=Elsevier.

[71] Lydenberg S, Rogers J, Wood D. From Transparency to Performance-Industry-Based Sustainability Reporting on Key issues; 2010. Available from: https://iri.hks.harvard.edu/files/iri/files/iri_transparency-to-performance.pdf.

[72] Fiaschi D, Giuliani E, Nieri F, Salvati N. How bad is your company? Measuring corporate wrongdoing beyond the magic of ESG metrics. Business Horizons. 2020 Jun;63(3):287-99. Place: Amsterdam Publisher: Elsevier WOS:000528200600006. Available from: http://www.webofscience.com/api/gateway?GWVersion=2&SrcAuth=DynamicDOIArticle&SrcApp=WOS&KeyAID=10.1016%2Fj.bushor.2019.09.004&DestApp=DOI&SrcAppSID=EUW1ED0F44jsXvHXHCrhJBRB8eO1J&SrcJTitle=BUSINESS+HORIZONS&DestDOIRegistrantName=Elsevier.

[73] Plan B. Våra projekt; 2022. Accessed: 2022-12-06. Available from: https://planbab.se/referenser/.

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