Towards Sustainable Construction

Developing a Framework for Identifying Ecosystem Services and Biodiversity Indicators in Compliance with CSRD

Master's thesis in Industrial Ecology

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Cover: Futuristic picture of Göinge by outside of Varberg, Sweden. Picture made by Derome AB.

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Abstract

With global population growth and increasing urbanisation, it is important to monitor and mitigate the impacts of land-use change on ecosystems and biodiversity. In order to foster a culture of accountability among companies, the EU has introduced the Corporate Sustainability Reporting Directive (CSRD), aimed at expanding the scope of sustainability reporting to include more companies. The aim is also to enhance the comparability, trustworthiness, and inclusion of relevant data in sustainability reporting. There are 13 Reporting standards within CSRD called European Sustainability Reporting Standards (ESRS), and the focus here is ESRS E4 which covers biodiversity and ecosystems. The aim of this master's thesis is to investigate how the construction and building company Derome can measure ecosystem services and biodiversity, and use the results to report this in line with CSRD.

This master's thesis is done in collaboration with Derome which is a company situated in the south-west of Sweden. From the fiscal year of 2025, Derome is obligated to report according to CSRD and ESRS E4, which means that Derome need to develop methodologies for measuring and monitoring their impact on biodiversity and ecosystems. A literature study and a semi-structured interview study with employees at Derome were conducted to achieve this. The results of this master's thesis shows that indicators, for ecosystem services and biodiversity can be identified using the combined framework, DPSIR-E. This framework, built upon the DPSIR (Drivers, Pressures, State, Impact, Response) model, incorporates three additional steps to ensure the development of suitable indicators: one dedicated to the actors engaged in indicator development, another focused on defining the purpose of the indicators, and a third dedicated to establishing evaluation criteria, resulting in the additional "-E" to the combined framework. The efficacy of this combined framework was demonstrated through its application to two of Derome's construction sites, resulting in the identification of 22 indicators measuring ecosystem services and biodiversity at Göinge by and Göingegården, including example values for Göinge by. Lastly, the importance of sector-specific disclosure requirements for the construction and building sector were identified. Further, common monitoring data points or indicators is needed to ensure comparable results regarding companies impacts on ecosystems and biodiversity within the sector.

Keywords: Ecosystem services, biodiversity, CSRD, ESRS E4, ecosystems, DPSIR, indicators, construction site

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Amanda Josefsson & Matilda Klintberg, Gothenburg, May 2024

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

CBD	Convention on Biological Diversity
CSRD	Corporate Sustainability reporting Directive
EA	Environmental Assessment
EC	European Commission
EEA	European Environmental Agency
EFRAG	European Financial Reporting Advisory Group
EGD	The European Green Deal
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ESs	Ecosystem services
ESRS	European Sustainability Reporting Standards
ESTIMAP	Ecosystem Services Mapping Tool
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
GBF	The Kunming-Montreal Global Biodiversity Framework
GHG	Greenhouse gasses
LUC	Land-use change
NCP	Nature's Contribution to People
NFRD	Non Financial Reporting Directive
NGOs	Non-Governmental Organisations
NVI	Natural Value Inventory
RPP	Relative Pollination Potential
RQ	Research Question
SDGs	Sustainable Development Goals
SME	Small Medium-sized Enterprises

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Introduction

Anthropogenic impacts on Earth are causing climate change, negative impacts on ecosystems and a worldwide decline in biodiversity (Neugarten et al., 2024). While the standard of living has increased for a majority of humans, the cost of converting habitats for economic advancement and societal development has had a negative impact on several million people due to climate change. The concept of planetary boundaries where first developed by Rockström et al. in 2009 and include descriptions on the state of different biochemical and biophysical systems and humanity's interference with these. According to Richardsson et al. (2023), six out of nine planetary boundaries have been overstepped which may result in irreversible damage on these systems and therefore alter the balance in nature and in ecosystems. The planetary boundaries and their status in 2023 is illustrated in Figure 1.1.

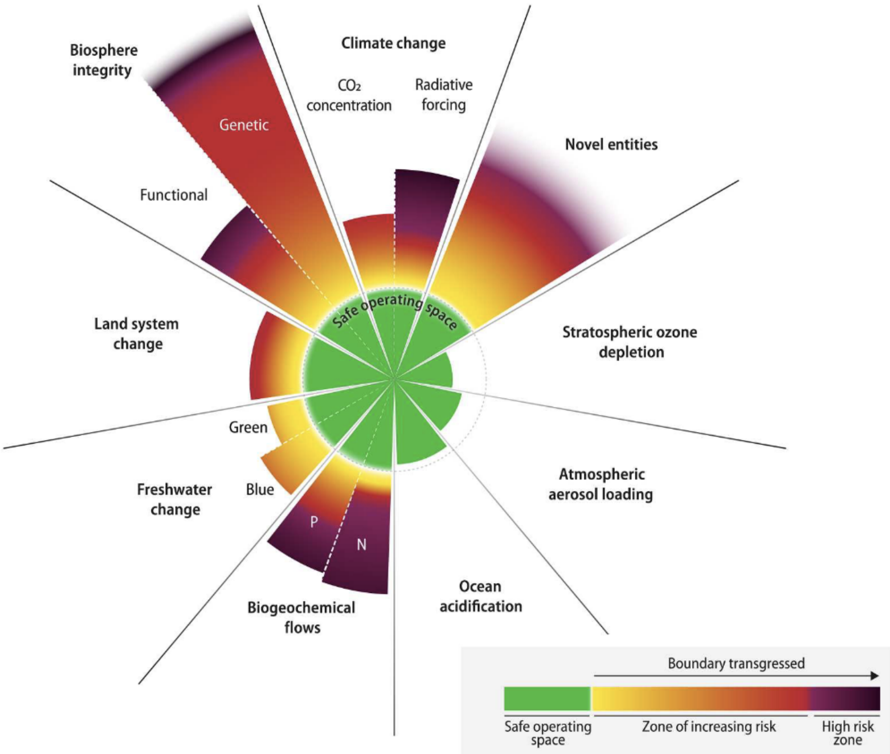


Figure 1.1: *The planetary boundaries and their status in 2023 which shows six out of the nine boundaries have been exceeded (Richardson et al., 2023). CC BY-NC 4.0*

Due to the current development in the world, including an increasing global population and urban expansion, securing production and availability of food and energy whilst ensuring a livelihood are of importance. Therefore, it is important to plan the development in urban expansion, energy production and agricultural activities to ensure the essentials of human life, since these sectors affect the environment

(Neugarten et al., 2024). Despite the coordinated planning for the future development of different sectors to ensure food, energy and livelihoods, development often does not aim to improve the conservation of ecosystems, ecosystem services (ESs) and biodiversity. Therefore, there is a conflict between maintaining nature and pursuing current development goals. In the article by Neugarten et al. (2024), the need for decision-making at a national and sub-national level regarding conservation and development is highlighted.

Initiatives like the Paris Agreement, the United Nations (UN) Sustainable Development Goals (SDGs) and the Kunming-Montreal Global Biodiversity Framework (GBF) are proof of an increased global recognition of climate change and its connection to biodiversity and sustainable development. However, as can be seen in Richardson et al. (2023) more efforts are needed to reverse the negative trend in the environment. Currently, large companies in the EU are obliged to disclose an annual sustainability report, including their impact on the environment (EC, 2023b). The latest sustainability reporting directive from the EU came into force on January 5th, 2023 and is called Corporate Sustainability Reporting Directive (CSRD) (EC, 2023b). The scope of CSRD is expanded from the previous one, both in terms of the number of companies included but also in the quality, comparability and transparency of the reports (EC, 2023b). Further, one aim of CSRD is to map and report on the whole value chain of the company along with providing in-depth disclosures on how sustainability issues impact a company's business and its activities' societal and environmental effects. Since Sweden is a member of the EU, companies operating in Sweden are obligated to report according to CSRD. However, there are no additional demands of reporting on ESs and biodiversity currently on a national level in Sweden. There are regulations on what is permitted and not in the Swedish Environmental Code and the Swedish Planning and Building Act, however these are not related to sustainability reporting.

Since results of measures in nature often have a high level of complexity, indicators can be used to provide simple yet accurate information on the current state in nature, e.g. for sustainability reporting. To evaluate ESs and biodiversity, quantitative indicators can be used to provide information regarding the state of nature (IPBES, nda). The indicators that are used to illustrate the state in nature must be of high quality and comprehensive to cover the issue that it is intended for. To ensure the quality of the indicators among other things, the European Environmental Agency (EEA) introduced the DPSIR framework (Drivers, Pressures, State changes, Impacts, Responses) to ensure that created indicators are of high quality (EEA, 1999). The EEA provides independent facts and is a part of the EU. The created indicators can be used to communicate the impact that a company has on ecosystems, ESs and biodiversity. Further, it can also be used to for sustainability reporting (EFRAG, 2023).

Derome is a construction and building company located in the south of Sweden which is to report their activities according to CSRD from the fiscal year of 2025 (A. Carlsson, personal communication, 23 February, 2024). Being a company within the construction and building sector, their activities are affecting ESs and biodiversity due to exploitation of land (Hald-Mortensen, 2023). Currently, in the municipality of Varberg Derome is building a new residential area called Göinge by and Göingegården.

1.1 Aim

The aim of this master's thesis is to investigate how construction and building companies can measure ESs and biodiversity regarding land-use, and report this in line with CSRD, more specifically ESRS E4. The company of Derome is the client of which specific indicators will be provided for one of their construction sites.

1.2 Research questions

Three main research questions (RQs) were compiled in order to reach the aim of the master's thesis:

1. How can ESRS E4 be applied on Derome's operations regarding land-use?
2. How can suitable indicators, regarding ESs and biodiversity, be identified by the usage of a framework?
   (a) For whom is the framework and the indicators designed to be used?
   (b) Who are the results of the indicators intended for?
   (c) What is the purpose of the indicators?
   (d) How can data be collected for the indicators?
3. What are suitable indicators derived from the created framework for measuring ESs and biodiversity at Derome's construction site, Göinge by and Göingegården?

The four sub-questions to RQ 2 address the meaning of the word "suitable" in the same RQ, since the definition of the word can vary. The four sub-questions ensure that the created combined framework can develop suitable indicators for the intended purpose, and the sub-questions are reviewed as criteria. The framework mentioned in RQ 2 can be applied to Derome, but also companies within the same sector.

1.3 Delimitations

This master's thesis focuses mainly on three aspects, both related to Derome's operations. Firstly, Derome's aim to measure their impact on ESs and biodiversity to further report on it, is a delimitation since the focus is on their operations. Another important delimitation is when developing indicators in RQ 3 it is for Göinge by and Göingegården only.

2

Topic Overview

This chapter presents an overview on ESs and biodiversity, relevant information regarding legislation on a national level and reporting demands on an international level. The company Derome and the geographical area, where the case study is located, is presented and the construction and building process in Sweden is described.

2.1 Ecosystem services & biodiversity

In this part, ESs and biodiversity are presented to gain insight of the importance of these topics. Further, drivers for biodiversity loss and red listed species are described as well.

2.1.1 Ecosystem services

ESs as a concept was first presented during the 1980s, addressing human dependency on the natural environment (Muradian and Gómez-Baggethun, 2021). Nature and ecosystems have an important role in sustaining human life and enhancing its quality, which is covered in the ESs concept (IPBES, 2019). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) formed in 2012, functions as an independent intergovernmental organisation with the purpose to enhance the connection between science and policy within biodiversity and ESs (IPBES, ndb). Nature provides essential elements for survival such as food, energy, medicine, a variety of materials and genetic resources. Additionally, nature and ecosystems actively regulates processes on Earth, contributing to the habitability of the planet for various living organisms (IPBES, 2019).

An ES is a type of service provided by an ecosystem due to its inherent functionality, e.g. pollination, nutrient cycling and fruit-and seed dispersal (IPBES, 2016). ESs are categorised into provisioning, regulating, cultural and supporting services depending on the type of service provided (MA, 2005). Provisioning ESs are products obtained from ecosystems e.g. food, fuel and freshwater. Further, benefits acquired from regulations of ecosystem processes are called regulating services and include climate regulation, disease regulation, water regulation and purification. Cultural services are non-material benefits from the ecosystem e.g. spiritual and religious, aesthetic, educational and cultural heritage. Lastly, supporting ESs are services provided by the ecosystem which are necessary for the production of all other ESs for example soil formation, primary production and nutrient cycling (MA, 2005). See Figure 2.1 for an illustration of the different types of ESs on land (NatureScot, 2023).

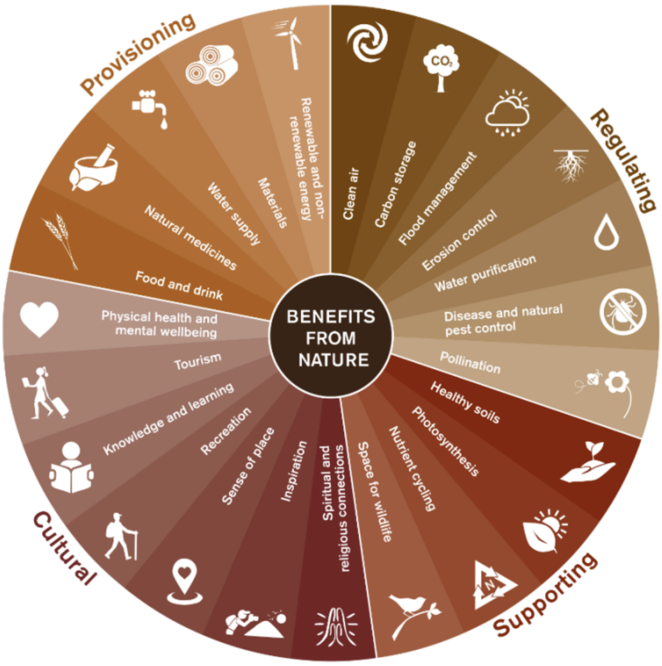


Figure 2.1: *Ecosystem services on land divided into the four categories (NatureScot, 2023). CC BY-NC 4.0*

The ESs framework presents a particular worldview that has its foundation in modern Western culture, and the main theme is the society/nature division. A hierarchical division between nature and humans, where humans are not only separated but above nature (Muradian and Gómez-Baggethun, 2021). ESs are crucial to humans because they significantly impact human well-being, however, they do not directly measure it. Although they are interconnected, ESs and human well-being are different entities. This is why it is essential to include ESs in the developed indicators, even though they do not directly measure human well-being but rather provide an estimation of its effects (Berghöfer and Schneider, 2015).

Ecosystems and ESs are not the same, but interconnected (IPBES, 2019). ESs are the direct and indirect contribution from the ecosystems which affects human well-being. They are therefore a way to assess and measure ecosystems by looking at the services they provide. The maintenance of ESs is important for the economy and human society, hence concern about ecosystem's protection must be raised (Muradian and Gómez-Baggethun, 2021).

Nature's Contribution to People (NCP) is a new and more inclusive term similar to ESs. NCP recognises the central role of culture between humans and nature instead of using economic terms as in ESs framework (Muradian and Gómez-Baggethun, 2021). The difference is that NCP includes both positive and negative contributions that nature has on human well-being (Muradian and Gómez-Baggethun, 2021; Díaz et al., 2018).

2.1.2 Biodiversity

One important supporting ESs is biodiversity. Biodiversity, or biological diversity, is according to Convention on Biological Diversity (CBD) defined as "... the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." (CBD, 2006). Environmental issues cause severe effects on the ecosystems on Earth which in turn may alter the possibility and conditions of future life on Earth, see Figure 1.1, where biodiversity, or biosphere integrity, is one of the planetary boundaries which has exceeded its tipping point. This means that the system approaches collapse which in turn will affect the environment and nature negatively (Richardson et al., 2023). To ensure that the balance in nature is maintained, biodiversity is important to preserve (EEA, 2020).

2.1.3 Drivers for biodiversity loss

Biodiversity loss is caused by multiple factors pressuring the balance of the ecosystems further towards their tipping point. There are both direct and indirect drivers which affect biodiversity loss, but in different modes of action. The direct drivers are factors that in themselves are affecting biodiversity and the ecosystem (Jaureguiberry et al., 2022). Indirect drivers may reinforce the direct drivers, or other indirect drivers, which in turn cause biodiversity and ecosystem alteration (Lazarova, 2017).

According to IPBES (2017), the direct drivers for biodiversity loss are "land-use change, climate change, pollution, natural resource use and exploitation, and invasive species". Land-use change (LUC) and sea-use change are caused by expansion in agriculture and urban areas and extraction of marine resources (Hald-Mortensen, 2023). With an increasing global population, urbanisation is predicted to expand accordingly (Grimm et al., 2008). According to IPBES (2017), LUC is "...the major human influence on habitats...". LUC affects biodiversity in a shorter time-span than climate change. Despite land-use altering biodiversity at a faster velocity, climate change is and will continue to affect biodiversity on a large scale. This argues for focus being laid on multiple factors rather than solely prioritising the immediate temporal driver.

Land-use in urban areas affects both the local and surrounding environment in terms of exploitation leading to disturbances in ecosystems. Further, the building materials used for the construction of the area result in effects on the ecosystem and biodiversity at other locations (Jianguo Wu et al., 2014). There is a positive correlation between societal and economic improvements and urbanisation, however the environmental impacts are often negative as land is transformed into urban areas and there is an increased need of raw materials for construction. "Urban Ecology" has been introduced to the field and is defined as "The study of spatio-temporal patterns, environmental impacts, and sustainability of urbanisation with emphasis on biodiversity, ecosystem processes, and ecosystem services" (Wu, 2014). Thus, by implementing the concept of urban ecology into the planning, the negative impacts of construction and living of urban societies on the environment can decrease.

2.1.4 Red listed species

Red listed species are a classification system created with the aim to give indications of a species status. Further, it is used by governmental bodies, NGOs and businesses etc. to assist in the assessment of species and if preservation actions are needed (SLU Artdatabanken, 2020). There are eight classifications on the species in the red list which are (SLU Artdatabanken, 2020):

- Extinct (EX)
- Extinct in the wild (EW)
- Regionally extinct (RE)
- Critically endangered (CR)
- Endangered (EN)
- Vulnerable (VU)
- Near threatened (NT)
- Least concerned (LC) (SLU Artdatabanken, 2020).

Further, there are two categorisations for species that lack data or are yet to be assessed. Threatened species are a type of classification in the IUCN Red list, which is divided into three classifications: vulnerable species, endangered species and critically endangered species (IUCN Standards and Petitions Committee, 2024). See Figure 2.2 for an illustration of the IUCN's red list categories.

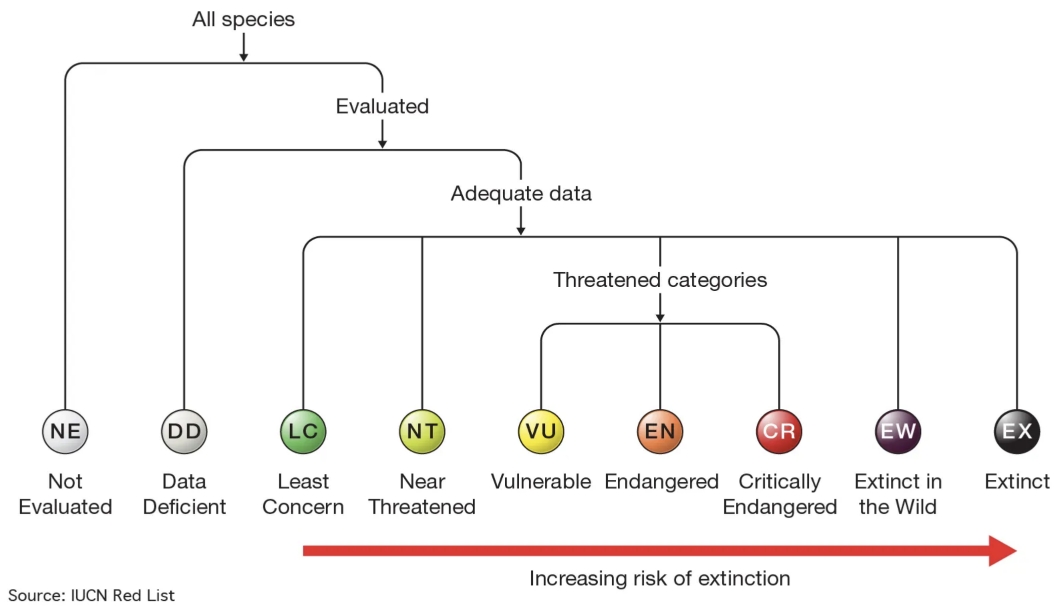


Figure 2.2: *IUCN's red list with the extinction risk according to nine different categories (Dublin, nd).*

2.2 International agreements & directives related to ESs and biodiversity

There are several international agreements and directives, mainly from the UN and the EU, which have the overall aim of improving the environment. The agreements and directives presented here are all addressing ESs, ecosystems and biodiversity.

2.2.1 International agreements

The SDGs were ratified by the UN and its member states in 2015. It consists of 17 goals including both social, economic and environmental objectives and includes goals relating to biodiversity (UN, 2015). Goal 14 "Life Below Water" and Goal 15 "Life on Land" are directly related to preservation and protection of ESs and biodiversity. Further, there is a correlation between preserving ESs and biodiversity for achieving SGD 2 (Zero Hunger), SDG 6 (Clean Water) and SDG 13 (Climate Action) (Saleh et al., 2024; UN, 2015).

Another international agreement is the GBF, initially the Post-2020 Global Biodiversity Framework. It was drafted in December of 2022 by the UN's Environment Programme with the main vision and goal "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people." (CBD, 2022). Further, the purpose with the GBF is to facilitate action, by implementing long-term goals for 2050, towards halting biodiversity loss by including governments, municipalities and regions.

2.2.2 The European Green Deal

The European Green Deal (EGD) was approved in December 2019 by the European Commission (EC) with the objective to reach climate neutrality within the EU borders by 2050 (European Council, 2023). It consists of a set of policies to set the EU on the pathway towards a green transition. The EGD is also a type of an overarching policy framework to reach the goal of climate neutrality (Dupont et al., 2024). Further, the EGD includes initiatives which address: climate, environment, energy, industry, agriculture, transport and sustainable finance in a cross-sectoral effort towards a sustainable future (European Council, 2023). Within the EGD, the aim is also to decouple resource-use from economic growth by 2050 in key areas (Fetting, 2020). "Preserving and Restoring Ecosystems and Biodiversity" is one of the main areas in the EGD, see Figure 2.3, which acknowledges ecosystems and biodiversity as important where LUC, sea-use change, direct exploitation of natural resources, and the impact of climate change are considered main drivers of biodiversity loss (Fetting, 2020).

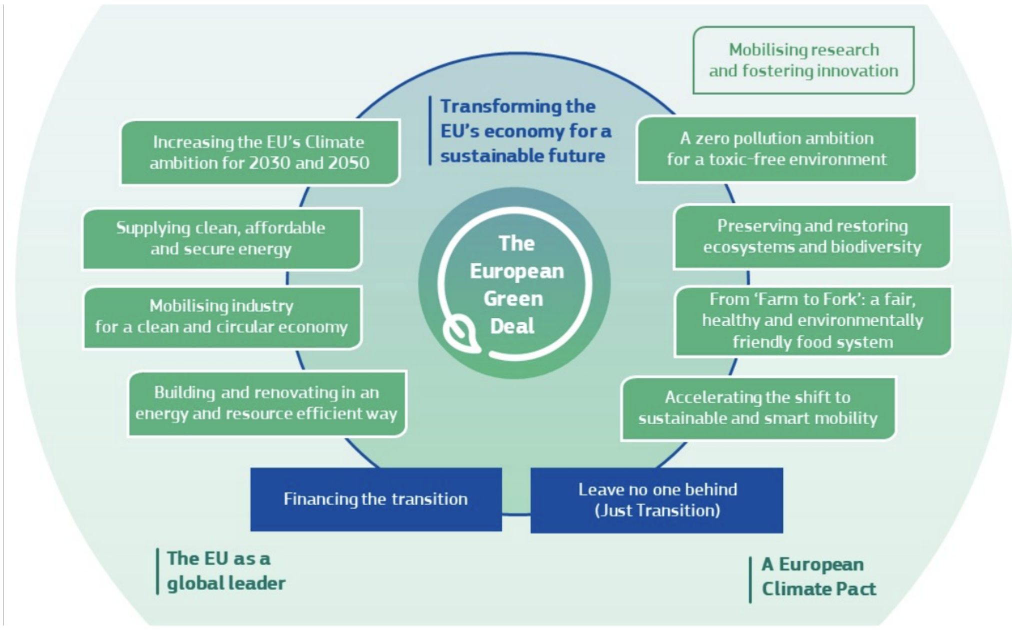


Figure 2.3: *The European Green Deal and its main areas (EC, 2019). CC-BY-4.0*

2.2.3 EU Biodiversity Strategy for 2030

To reduce the degradation of the ecosystems and ensure that nature and its ecosystems gets acknowledged in policy making, the EU created the "EU Biodiversity Strategy for 2030" in 2021. It provides a framework consisting of multiple targets and actions that the member states need to align with (EC, 2023a). The framework consists of four pillars which aim to create plans leading to actions for improving and protecting biodiversity until 2030 and are defined as (EC, 2023a);

- Pillar 1: Protecting nature in the EU
- Pillar 2: Restoring nature in the EU
- Pillar 3: Enabling transformative change
- Pillar 4: A global biodiversity agenda (EC, 2023a).

The EU Biodiversity Strategy for 2030 encourages a wider and stronger protection of habitats and species than previous legislation (EC, Directorate-General for Environment, 2021). To ensure an increased protection of habitats aligned with the framework, 30% of land and sea area require protection. A third of the area should be covered by an even stricter preservation status, corresponding to 10% land and sea area respectively.

2.2.4 The EU Birds and Habitats directives

To protect and preserve Europe's vulnerable species and habitats there are two directives from the EU, each addressing one of these categories (EC, 2015). The Birds Directive was adopted in 1979 and has the objective to protect all wild birds and their habitats in the EU. The Habitats Directive was adopted in 1992 and expanded the scope of the Birds Directive to another 1000 rare, threatened, or endemic species of wildlife and flora, commonly known as species of European significance. The two directives have overall the same aim, to safeguard species and habitats, which is why they are referred to as one (EC, 2015). The species and habitats which are protected through the directives are supposed to be restored to a "favourable conservation status throughout their natural range within the EU" according to the European Commission (2015).

2.3 Sustainability reporting: CSRD & ESRS E4

Reporting on the environmental impact that a company has was initiated in the 1980s whilst social impacts and responsibility was reported upon in the 1960s (United Nations Environment Programme, 2019). To ensure the use of common terminology when reporting on impacts, the Global Reporting Initiative (GRI) among others was established in 1997, becoming the most widely adopted standards organisation. GRI includes different standards including universal, sector-specific and topic standards (GRI, nd). However, reporting according to the GRI standards is voluntary leading to many companies lacking sustainability reports.

2.3.1 CSRD

As a part of the EGD, the EC developed the CSRD from the former directive, the Non-Financial Reporting Directive (NFRD) estabilsed in 2014 (EC, 2023b). CSRD is a standardised format for corporate sustainability reporting and it came into power in January 2023. In addition, CSRD is a consolidated version of the NFRD since it was no longer adequate to achieve the goals of the European Green Deal (Odobaša and Marošević, 2023). Consequently, this new directive is more thorough since it ensures reporting that is more comparable, trustworthy and includes relevant data regarding risks and opportunities across various dimensions of sustainability (Odobaša and Marošević, 2023). It expands the scope of sustainability reporting by including all large companies that meet the criteria (EC, 2023b):

- Have more than 250 employees
- At least €40 million in turnover
- At least €20 million in total assets (EC, 2023b).

Further, CSRD also includes Small and Medium-sized Enterprises (SMEs), which the former directive, NFRD, did not (EC, 2023b). CSRD's application is mandatory from the fiscal year 2024 meaning that the reports will be published in 2025. The published corporate sustainability reports will be made available to the public with the intentions that individual businesses will gain a clear insight of their own impact in all aspects of sustainability (Odobaša and Marošević, 2023). The reports will be advantageous for customers, investors, Non-Governmental Organisations (NGOs), policy-makers and for the EU and can be used to compare the progress of the company. When viewing the results from the reports, the development and progress can be monitored. The goals to be achieved are outlined in the SDGs, the Paris Agreement, the EGD and other delegated acts which aims to transition into a sustainable future (Odobaša and Marošević, 2023).

According to CSRD, the companies have to report in line with the European Sustainability Reporting Standards (ESRS) and an accountant from a audit firm needs to revise it (EC, 2023b). The report has to be third-party assured and the audit firms are allowed to apply national assurance standards. Auditors must fulfill certain criteria beyond the educational qualifications mandated by the Audit Directive 2006/43/EC to conduct assurance engagements for sustainability reporting. The assessment of professional competence is intended to ensure that they have the required theoretical knowledge and can apply this knowledge (Accountancy Europe, 2023). Further, it is the independent body of the European Financial Reporting Advisory Group (EFRAG) who developed these standards that were published in December 2023 (EU, 2023). There are in total 13 ESRS that cover all sustainability issues and ESRS E4 specifically covers ecosystems and biodiversity, see figure 2.4.

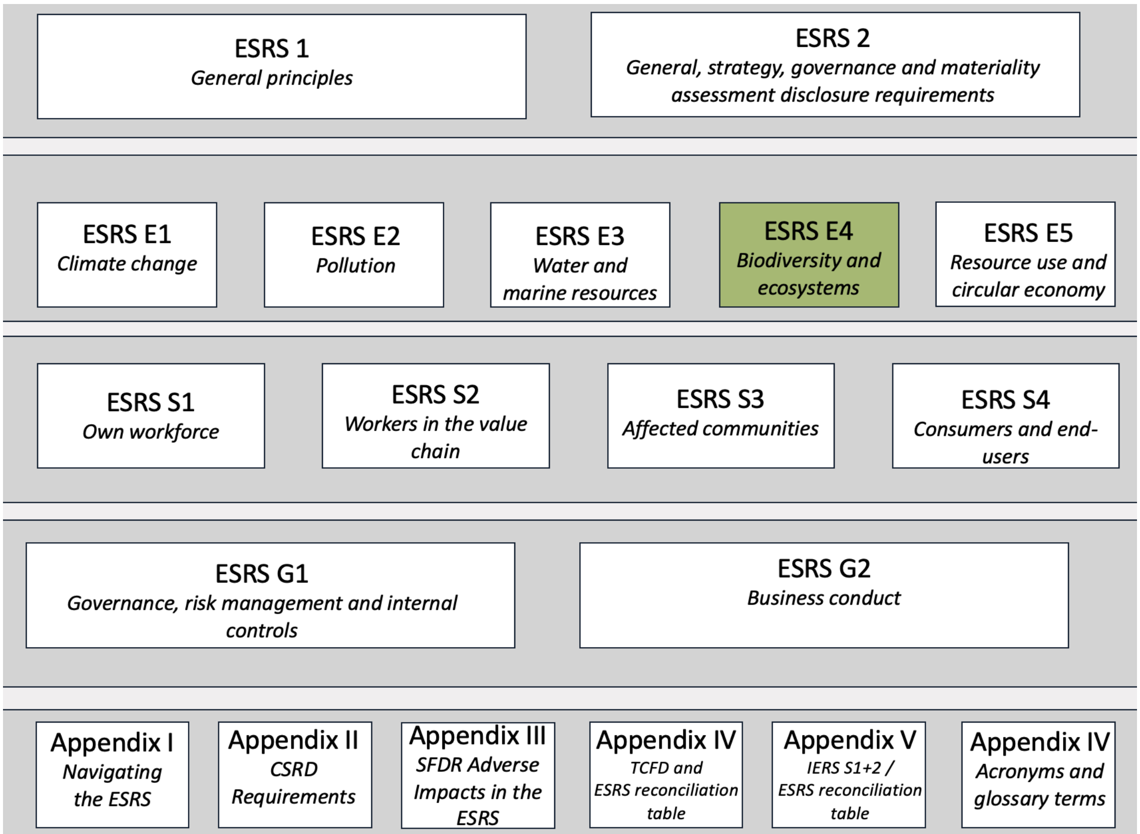


Figure 2.4: *The 13 ESRS, where the ESRS E4 addresses biodiversity and ecosystems and is highlighted in green. Based on and modified from EFRAG & Raad voor de Jaarverslaggeving (2022). CC BY-NC 4.0*

The ESRS covers five different areas of sustainability. The Environmental Standard cover: climate, pollution, water and marine resources, biodiversity and ecosystems, resource use and circular economy (EU, 2023). The different environmental standards are interconnected since nature and environment consist of systems that are all dependent on each other. These interactions are between ESRS E4 and; ESRS E1 (Climate change), ESRS E2 (Pollution), ESRS E3 (Water and marine resources) and ESRS E5 (Resource use and circular economy) (EFRAG, 2023).

2.3.2 ESRS E4

Reporting on a company's impacts on biodiversity and ecosystems has not been mandatory prior to the upcoming legislative reporting demand that is CSRD, and ESRS E4. The Disclosure Requirements states what type of information and data that the companies should include in their report (EFRAG, 2023). There are in total three categories within the ESRS E4: Strategy, Impact, risk and opportunity management and lastly Metrics and targets and a total of eight disclosure requirements:

- ESRS E4-1
- ESRS 2 SBM-3
- ESRS 2 IRO-1
- ESRS E4-2
- ESRS E4-3
- ESRS E4-4
- ESRS E4-5
- ESRS E4-6

There are disclosure requirements from ESRS 2 included in the ESRS E4 since it includes "General, strategy, governance and materiality assessment disclosure requirements" meaning it is more general. The aim of the requirements in ESRS E4 is to ensure that companies, within their sustainability reporting, provide clear information on: their impact on biodiversity and ecosystems and the measures taken by the company to prevent or mitigate negative impacts, and to safeguard and restore biodiversity and ecosystems, as well as to manage associated risks and opportunities (EFRAG, 2023). Further, the company's strategies and ability to adapt its business model including notable risks, dependencies, and opportunities linked to the company's biodiversity and ecosystems, along with how they are managed should be disclosed in the sustainability reports. The financial implications of significant risks and opportunities stemming from the company's effects on, and reliance on, biodiversity and ecosystems, which may affect the company over the short, medium, and long term should be included (EFRAG, 2023). To summarise, the aim of the Standard is to comprehend the impacts on biodiversity and ecosystems, both positive and negative, and the potential contributions to the drivers of biodiversity loss and ecosystem degradation (EFRAG, 2023). Further, any mitigation or prevention actions for biodiversity loss and ecosystem degradation is also important to understand. ESRS E4 mentions the importance of addressing possible actions being taken in relation to the mitigation hierarchy which can be seen in Figure 2.5.

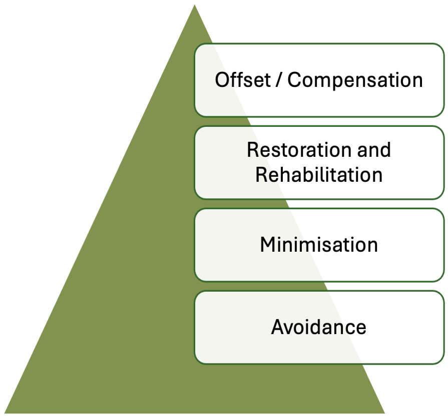


Figure 2.5: *Mitigation hierarchy. Illustration based on EFRAG (2023) and made by authors. CC BY-NC 4.0*

Further, the corporation should align its strategy with EU-directives, and UN goals and targets. Both dependencies and opportunities related to ESs and biodiversity and how these are handled and the financial effects from the dependencies and impacts are included in the goals of this Standard (EFRAG, 2023). This Standard mandates organisations to disclose information about their impact on terrestrial, freshwater, and marine habitats, biodiversity within and between species, ecosystem diversity, and their interactions with indigenous peoples and other affected communities, according to the CBD's definition of biodiversity. For an overview of ESRS E4, see Table 2.1.

Table 2.1: *An overview of the Disclosure requirements in the ESRS E4, and a short description of what each entails (EFRAG, 2023; Deloitte, 2024).*

Category	**ESRS Disclosure Requirement**
Strategy	**E4-1:** Disclose information on how the impacts on biodiversity and ecosystems, dependencies, risks, and opportunities arise from and the adaptation of its strategy and business model. **E2 SBM-3:** The company is required to provide a compilation of significant operational sites within its operations and disclose any adverse effects on regions having delicate biological diversity, along with their impacts and interdependencies. Additionally, it must assess the ecological condition of these areas and pinpoint those harbouring sensitive biological diversity.
Impact, risk and opportunity management	**E2 IRO-1:** Explanation of procedures for recognising and evaluating important impacts, hazards, interdependencies, and potentialities concerning biodiversity and ecosystems. **E4-2:** The company's strategies for addressing substantial impacts, risks, interconnections, and potential benefits associated with biodiversity and ecosystems. **E4-3:** The measures implemented by the company concerning biodiversity and ecosystems, along with the resources appointed for their execution.
Metrics and targets	**E4-4:** Objectives established by the company for biodiversity and ecosystems. **E4-5:** Indicators of the company's significant effects on biodiversity and ecosystems. **E4-6:** Anticipated financial outcomes from significant risks and opportunities linked to biodiversity and ecosystems.

The **ESRS E4-1** titled "Transition plan and consideration of biodiversity and ecosystems in strategy and business model" belongs to the first category: **Strategy** (EFRAG, 2023). The aim is to facilitate the comprehension of the resilience in the business strategy and the company's strategy should be described in terms of the resilience of the strategy and business model both in relation to biodiversity and ecosystems (EFRAG, 2023). In total there are two Disclosure Requirements in the Strategy category, and the other one is called **ESRS E2 SBM-3**: "Material impacts, risks and opportunities and their interaction with strategy and business model" (EFRAG, 2023). Identifying the impacts and dependencies to the ecological status of the areas and negative impacts in relation to land degradation, desertification and soil sealing. Lastly, it should be included if the sites affect threatened species (EFRAG, 2023).

The next category called **Impact, risk and opportunity management** includes firstly the Disclosure Requirement which is **ESRS E2 IRO-1** called "Description of processes to identify and assess material biodiversity and ecosystem-related impacts, risks, dependencies and opportunities" (EFRAG, 2023). A scenario analysis regarding ecosystems and biodiversity can be included to identify and assess the risks in different time horizons. The company has to disclose if its sites are located near a bio-sensitive area, and if its activities negatively affect these areas. If there have been biodiversity mitigation measures implemented according to several Directives from the EU, this should also be included. Next, the Disclosure requirement **ESRS E4-2** with the title "Policies related to biodiversity and ecosystems" is also included in the same category (EFRAG, 2023). In general, it states that the policies implemented by the company concerning biodiversity and ecosystems, along with the resources designated for their execution should be conveyed. The aim with it is to understand the extent of the company's effort in addressing biodiversity and ecosystems with regards to policies and action (EFRAG, 2023). "Actions and resources related to biodiversity and ecosystems", **ESRS E4-3**, has the goal for the company to realise the key actions, both planned and taken, to reach targets and objectives regarding biodiversity and ecosystems. Furthermore, the aspects of biodiversity offsets in action plans should be disclosed including the aim, financing effects and a thorough description of the offsets (EFRAG, 2023).

The category is **Metrics and targets** and includes three Disclosure Requirements: ESRS-E4-4, ESRS E4-5 and ESRS E4-6. Firstly, the **ESRS-E4-4** with the title "Targets related to biodiversity and ecosystems" has the purpose of disclosing how the adopted targets can reinforce the policies related to biodiversity and ecosystems, and highlight the important impacts, dependencies, risks and opportunities. Further, the company should include information on ecological thresholds and allocation when creating goals. References to both the GBF and relevant aspects of the EU Biodiversity Strategy for 2030 have to be disclosed as well. **ESRS E4-5** is defined according to EFRAG (2023) as "Impact metrics related to biodiversity and ecosystems change" with the objective of emphasising the performance of a company concerning substantial impacts on biodiversity and ecosystems. Data points related to the identified sites located near or in biodiversity-sensitive locations if the company directly contributes to the impact drivers of LUC, freshwater-use change and sea-use change have to be disclosed (EFRAG, 2023). Finally, the Disclosure Requirement **ESRS E4-6**, called "Anticipated financial effects from material biodiversity and ecosystem-related risks and opportunities" is an exception since the first year of reporting, the company does not need to disclose this information (EFRAG, 2023).

2.4 Swedish residential development process

In Sweden, several legal documents and assessments guide the process from land to the development of a residential area. This process involves legislation such as the Swedish Planning and Building Act (Plan och bygglagen in Swedish) and the Swedish Environmental Code (Miljöbalken in Swedish), as well as assessments like the Strategic Environmental Assessment (SEA, Strategisk miljöbedömning in Swedish), Natural Value Inventory (NVI, Naturvärdesinventering in Swedish), and Environmental Impact Statement (EIS, Miljökonsekvensbeskrivning in Swedish).

Furthermore, the process involves various stakeholders, including the municipality, companies, locals, governmental agencies and consultancies.

2.4.1 Municipal comprehensive planning process

The municipality needs to make a comprehensive plan for the whole municipal area with the aim to show how the land and water should be used in the long term (Boverket, 2024). The comprehensive plan should be updated every 10th year to stay current (M. Johansson, personal communication, 23 February, 2024). The Swedish Planning and Building Act states what should be included and how the process to create a comprehensive plan looks like (Boverket, 2023). The Swedish Planning and Building Act was implemented in May 2011 with the aim to ensure a sustainable living environment within Sweden including the environmental impacts of the construction, societal and economic aspect (SFS 2010:900, 2010a).

Further, a SEA is conducted to identify and evaluate the potential environmental impacts of the comprehensive plan, and is included in this process of creating it according to the Swedish Planning and Building Act. It is stated in the The Swedish Environmental Code on how this assessment should be done. The Swedish Environmental Code, was established in 1999 with the aim to ensure both inter- and intragenerational equity regarding the environment and human health (Naturvårdsverket, ndb). It covers all of the activities and projects impacts on the environment and does not distinguish between business-related and private activities. EU directives regarding sustainability are incorporated into the Swedish Environmental Code (Naturvårdsverket, ndb; EC, 2015; EC, Directorate-General for Environment, 2021). More details about the Swedish Environmental Code is in Appendix A.3.

2.4.2 Permission process for initiation of construction

Before a company initiates the construction process on a certain area, permission is needed. To generate more information regarding the land, a detailed comprehensive plan is created by the municipality from the municipal comprehensive plan (Boverket, 2024). A detailed comprehensive plan is a development plan in a smaller area in the municipality, and contains more details about the development of the land and water. This plan has a smaller geographical scope which results in a more detailed description of cause-and-effect chains. This includes doing both a NVI and an EIS of the area, to assess the status of nature and the effects on the environment. The EIS should include the state of the environment in the area and possible impacts that the project might have (SFS 1998:808, 6 ch. 11§). It is the business practitioner who is responsible for conducting an EIS. The consequences and effects of a project should be included in the EIS (Ryegård and Åkerskog, 2020). A NVI is a report of the quality of the area, regarding biodiversity and natural value, and is done according to the SIS-standard (Boverket, 2021).

Similar to the comprehensive plan, the detailed comprehensive plan is not legally binding but should be viewed as material used when constructing the detailed development plan. After these plans are developed and read, the company decides if they want to invest in buying the land (M. Johansson, personal communication, 23 February, 2024). The purchase of the land is then followed by the company handing in a planning notification to the municipality which then decides if the company is permitted to build on the land. If the planning notification is approved by the Building Committee, a time frame is given which explains when the project can be initiated. The planning process can take up to two to four years which includes the process of the municipality, together with the company, to construct a detailed development plan. The detailed development plan includes processes such as consultation of relevant actors, reviewing and adopting of the plan. The process of adopting a detailed development plan, enables parties such as the Swedish Transport Administration (Trafikverket in Swedish), the county administration or private persons, to appeal. If no appeal is handed in, the detailed development plan comes into force within approximately four weeks. The company then appeals for building permits which is followed by selling off the residential plot, construction of the residential buildings and lastly access is given to the buyers (M. Johansson, personal communication, 23 February, 2024).

2.4.3 Natural Value Inventory

In most cases, the municipality includes a NVI in the detailed development plan with the aim to map the status of nature in that area, and provide important information about the area. NVI's are often used as a basis for EISs (Boverket, 2021). It is a report of the quality of the area, regarding biodiversity and natural value, and is done according to the SIS-standard by consultants who often are ecologists. However, it is not considered a sustainability report since it is not used by companies or authorities to assess their impact on nature. The inventory can be done with varying levels of detail but should entail information on the type of biotope which can act as a base for mapping and analysing the ESs (Boverket, 2021). The NVIs should include assessments on the value of nature in the area which ranges from one to four, where one indicates a high natural value and four some natural value. There are classifications between five and seven but these are rarely included in the inventory due to them being classified as having a low or even negative contribution to biodiversity or natural value. The different classifications include assessments regarding conservation species, red listed species and assessments regarding the value of that area in terms of biodiversity on both regional, national and global level. The highest natural value (nature valuation class 1) entails that the area has a very significant importance for biodiversity and the lower the classification, the lower natural value (Boverket, 2021).

In Sweden, there are seven different types of general Biotope protection areas that are legally protected which are (Naturvårdsverket, 2023):

- lines of trees
- springs with surrounding wetlands in agricultural areas
- willow banks

- small watercourses and wetlands in agricultural areas
- stone fences in agricultural areas
- small stands of trees and bushes or rocks in the midst of a field (Naturvårdsverket, 2023).

The reason for legally protecting these areas is their specific importance for preserving biodiversity in Sweden. Further, the Biotope protection areas enable Sweden to reach international and national goals stated by the CBD and the Swedish Parliament (Naturvårdsverket, 2023). These seven areas are decided upon by the Swedish government and are valid in all of Sweden. However, the municipalities and county administrations have the authority to characterise the area with additional biotope protection areas. In the geographical context of Sweden, these seven protection areas are important for biodiversity (Naturvårdsverket, 2023). Information regarding this can be found in the NVI for each area.

2.5 Indicators & frameworks

According to IPBES, indicators can be defined as "... a simple, measurable and quantifiable characteristic or attribute responding in a known and communicable way to a changing environmental condition, to a changing ecological process or function, or to a changing element of biodiversity" (IPBES, nda). In connection to this, frameworks can be used to identify indicators. A conceptual framework can be defined as a way too "simplify thinking, structure work, clarify issues and provide a common reference point" (Potschin-Young et al., 2018). There are many connections between indicators and conceptual frameworks which can be utilised for identifying indicators, and this will be presented here.

2.5.1 Indicators

Since indicators help monitor and mirror the trends occurring in nature in a holistic manner, they have become valuable for policymakers. However, it is difficult for policymakers to grasp the meaning of the indicators since indicators might be complex, many and there exists such a variety of them. The main aim of environmental indicators are communication, producing information on the current issue they are monitoring (Gabrielsen and Bosch, 2003). Communication with policymakers requires simplifying the data to make it understandable, indicators can be used. In other words, environmental indicators are a simplification of a complex reality and usually focus on individual aspects, one at the time. According to the European Environmental Agency (EEA) and Gabrielsen and Bosch (2003) there are four purposes of environmental indicators:

- To supply information on environmental problems, in order to enable policy-makers to evaluate their seriousness;
- To support policy development and priority setting, by identifying key factors that cause pressure on the environment;

- To monitor the effects and effectiveness of policy responses, and
- To raise public awareness on environmental issues. Providing information on driving forces, impacts and policy responses is a common strategy to strengthen public support for policy measures (Gabrielsen and Bosch, 2003).

However, when using indicators there is always a risk of missing important aspects of the issue in question. Since the indicators only demonstrate the parts of the reality it is supposed to, there is a risk of misleading results (Meadows, 1998). Indicators can be developed with the help of frameworks, to assess the relations between human activities and the environment. One example used by the EEA is DPSIR due to its simplicity and applicability of communicating environmental trends with the help of indicators (Gabrielsen and Bosch, 2003).

2.5.2 Evaluation of indicators

When creating indicators to assess a situation, it is important that the indicators are evaluated to make sure they fit. In the framework PICABUE, its last step, the evaluation step, covers this. PICABUE is a framework to develop indicators that concerns sustainability and consists of seven steps (Mitchell et al., 1995). The evaluation step is where the final sustainability indicators are reviewed (Mitchell et al., 1995). In this particular step there are eight areas to cover:

1. Relevance and scientific validity
2. Sensitive to change across groups
3. Sensitive to change over time
4. Consistency of data
5. Comprehensible
6. Appropriate data transformation
7. Measurable data
8. Possible targets or threshold values (Mitchell et al., 1995).

A similar, but more simple evaluation method is presented in Brown et al. (2014) and are as follows:

- Relevant to the user's needs.
- Understandable – conceptually how the measure relates to the purpose, in its presentation and in the interpretation of the data.
- Useable - for measuring progress, early warning of problems, understanding an issue, reporting, awareness raising etc.
- Scientifically sound – an accepted theory of the relationship between the indicator and its purpose, with agreement that change in the indicator does indicate change in the issue of concern and that the data used is reliable and verifiable.
- Sensitive to relevant change/issues.
- Practical and affordable – to ensure its continued use and in this way improve the rigour of the indicator as longer time series are collected (Brown et al., 2014).

The first criteria is related to the purpose, the user and the intended audience of the indicator. The second criteria touches upon that the indicator must be understandable for the one who is creating the indicator, to the extent that the person can put the indicator into context. With context, it is meant that the indicator can be connected to other environmental issues and explained to show its interconnectedness (Brown et al., 2014). The third criteria includes evaluations regarding if the indicator can be measured or not and whether data regarding the indicator is available. The availability of data can vary between different actors, and availability to data is connected to access to knowledge (Brown et al., 2014). To give an example, a consultant might be needed for executing this and depending on the economics for an actor, this can be more or less difficult. Further, the results of the measurements must also give information regarding possible changes in nature to monitor the impacts and its effects on nature. Lastly, the fourth criteria entails the importance of using indicators that are well established to ensure the validity (Brown et al., 2014). This can be achieved through either using governmental data and research about the topic or use established literature.

2.5.3 Conceptual frameworks

The creation of a conceptual framework is considered to be the first step in ecosystem assessment. Examples of conceptual frameworks within the area of ESs and biodiversity are DPSIR and ecosystem services cascade (EEA, 1999; Zhang et al., 2022). DPSIR is used for framing and assessing environmental issues, and is widely recognised in research. Further, there are frameworks which are methodological, e.g. PICABUE (Mitchell et al., 1995), which aims at measuring ecological integrity with a variety of spatial and geographical scales. Depending on the purpose of using a framework, different frameworks will be a better fit than others.

2.5.4 DPSIR

To measure and assess changes and state in nature and the environment, the European Environment Agency (EEA) developed the causal DPSIR framework (EEA, 1999). The primary objective of the framework was to offer its audience, which was first aimed at policymakers, an understanding of environmental impacts. Further, the framework aims at capturing the issues in a holistic manner including the multiple feedback loops that an environmental issue constitutes of (Moss et al., 2021). The DPSIR framework is iterative and the relations between the components is described in figure 2.6.

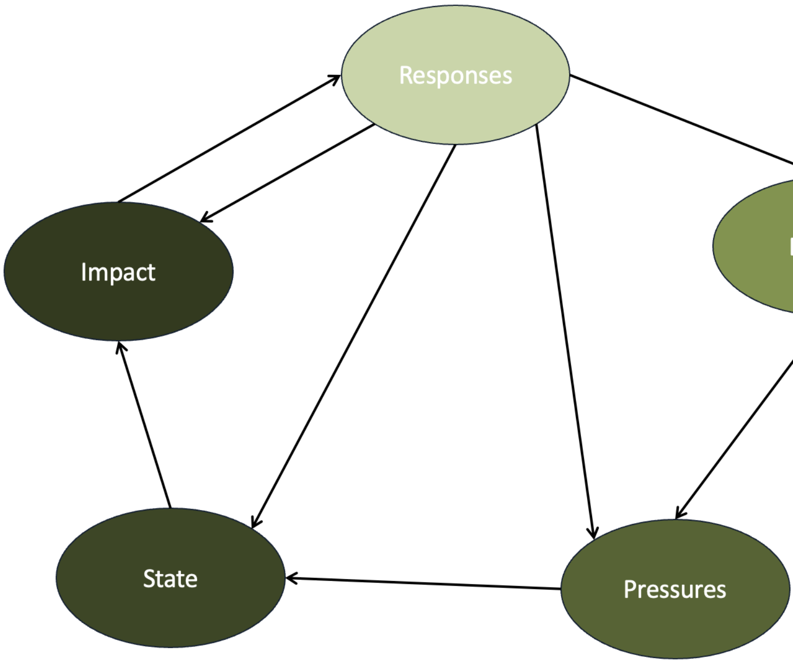


__Figure 2.6:__ The DPSIR framework. Modified from EEA (1999) and made by the authors. CC-BY-4.0

Drivers refer to the social, demographic and economic shifts within society which consequently influence changes in lifestyles, overall consumption levels, and patterns of production. Driving forces in this sense are the root causes in society which bring significant changes to the environment (EEA, 2003). Pressure indicators define the change in dispense of emissions, both biological and physical agents, and the allocation of land resulting from human activities. In other words, the human activities which can affect the environment in this case. Next, the state changes indicators provide a description of physical, biological and chemical phenomena in a specific area. These descriptions of the states in the area are related to the pressures mentioned, and what these pressures could lead to. These pressure changes cause effects, impacts, on the functions on the environment, including human and ecosystem health, depletion of manufactured capital, the availability of resources and biodiversity (EEA, 2003). Impacts in this perspective are the consequences of the state changes, and what different repercussions it can lead to. One impact can be linked to several state changes. The responses encompass the actions undertaken by various societal groups, governmental efforts with the objective to prevent, compensate, improve or adapt to changes in the environmental state. These actions could be directives, legislation or investments that are based on the effects on the environment (EEA, 2003).

According to Moss et al. (2021), using the DPSIR framework is suitable for assessing effects on ecosystems and biodiversity decline on both a larger and smaller scale, both globally and nationally. Since most of the drivers for biodiversity decline and disturbances on ESs are related to societal and economic factors, it is important to consider these with the aim of understanding the causes and responses to increase the compatibility when using it for assessing ecosystem and biodiversity (IPBES, 2019).

2.6 Introducing Derome, Göinge by & Göingegården

This section introduces Derome and their operations in Varberg known as Göinge by and Göingegården. It also includes maps, NVIs, and EISs of the area.

2.6.1 Derome

Derome was founded in 1946 in Sweden and is a family-owned company within the construction and building sector (Derome, 2023b). Derome has the whole value chain from forest to finished houses and products. As of 2022, the Derome Group reported a total turnover of 12.1 billion Swedish crowns and employed 2614 individuals (Alla Bolag, 2023). Due to its size, Derome is obliged to report in accordance with the CSRD directive, although compliance will commence from 2025 due to its non-listed status as of 2024 (A. Carlsson, personal communication, 23 February, 2024).

2.6.2 Göinge by & Göingegården

Göinge by and Göingegården are developing into a residential area, under Derome's direction, located north of Varberg in the county of Halland, southern Sweden. Varberg municipality, located on the coast, is home to approximately 68 000 residents (Varbergs Kommun, 2023). The project was initiated in 2008, with Göingegården completed in 2020 and Göinge scheduled for completion in 2025-2026 (Derome, ndb; Derome, nda). The development consists of approximately 1400 residential housing and includes properties of apartments (both rentals and ownership), semi-detached and detached houses. Prior to Derome's operations, the area consisted mainly of agricultural land and apple orchards. This has been preserved to some extent in the current residential area where the orchard acts as a social area. For an overview of the area see Figure 2.7.

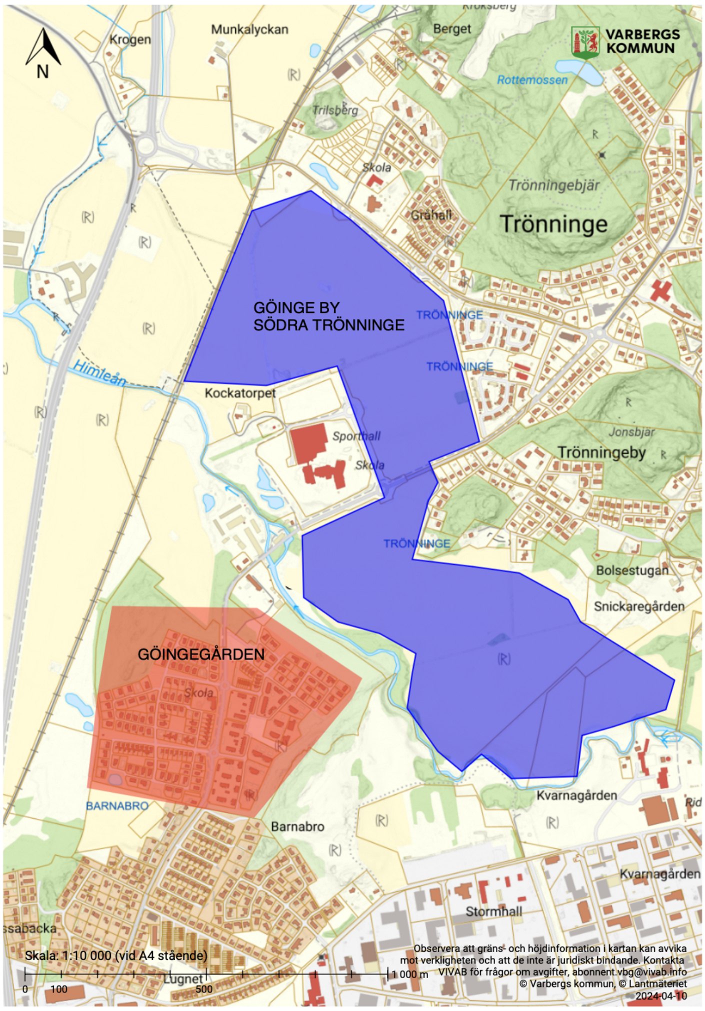


Figure 2.7: Map over the area including both Göinge by and Göingegården (M. Johansson, personal communication, 10 April, 2024). Published with permission by Derome.

According to an EIS conducted by Ramboll in 2016, potential impacts of the project on the surrounding environment include effects on birds and human health. The prior area included fields which are important habitats for birds, including red-listed species, that were assessed to be impacted negatively. Surrounding Natura 2000-areas may be affected negatively due to the project's impact on storm water flow in Himleån. Lastly, the construction of a bridge over Himleån is expected to have a large negative impact on surrounding nature. This area is classified with a high natural value classification which increases the severity of the impacts on this area. It is also assumed that the construction will lead to increased traffic flow leading to even further disturbances on the surrounding (Lindved, Håkan, 2016).

The results from the NVI for the area shows that there are ten areas that were identified as important for biodiversity which can be seen in Figure 2.8 (Sörensen, 2015).

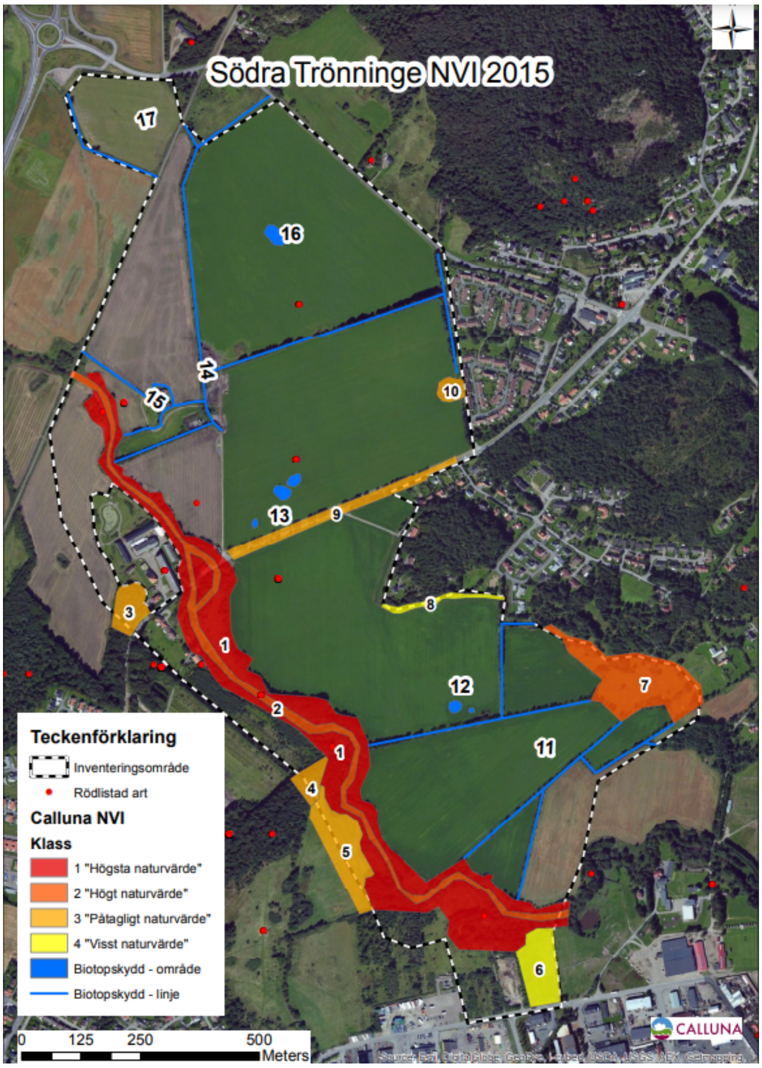


Figure 2.8: *Results from the NVI at Göinge by (Sörensen, 2015). Published with permission by Varberg Kommun.*

Further, according to Sörensen (2015) in the NVI about Södra Trönninge, including Göinge by and Göingegården the most important remarks are:

- The construction site is located on agricultural land
- Ten areas have been assessed according to the SIS-standard and given a natural value
- Seven biotope protection types have been identified
  - The seven biotope protection types have an assigned natural value
- 15 conservation species have been identified: including signal species, red-listed species and protected species (Sörensen, 2015).

3
Method

This section outlines the approach taken to address the RQs and answering of the aim. The collaboration with Derome acts as a cornerstone, with the company's need for knowledge gathering about CSRD, ESs and biodiversity within their operations. The method consists of explanation regarding the:

- Data collection of secondary and primary data
  - Literature study
  - Framework & indicator search
  - Interview study with employees at Derome
  - Personal communication
- The combined framework DPSIR-E
- Case study of Göinge by and Göingegården
- Delimitations

Both Swedish and English sources were used throughout the working process due to the geographical scope of the masters thesis.

3.1 Data collection

Both secondary and primary data were collected throughout the process. A literature study was conducted to collect secondary data including legislation, framework and indicator searches. An interview study and personal communication were conducted to gather primary data.

3.1.1 Literature study

The literature study served two main purposes: generating information regarding the scope and background, and collecting secondary data to address the RQs. Initially, reports, articles and the master's thesis written by Andréasson (2023) was used for identification of relevant references related to the field of ESs, biodiversity and sustainability reporting. Regarding legislation, the different directives and legislation are often interconnected which resulted in the identification of additional legal documents relevant for this case. See Table 3.1 for an overview of the main types of searches included in the literature study, the search engine used and the main search words used for each type of search. For an overview of all search words, see Appendix A.1.

Table 3.1: *The type of search, search engines and key search words are displayed to summarise the literature study.*

Type of Search	Search Engine	Main Search Words
Background	Google Scholar, Scopus	biodiversity, ecosystem services, drivers and biodiversity loss
Legislation	Google, Governmental agencies, European Commission	Miljöbalken, Sveriges miljömål, Plan-och bygglagen, European green deal, EU biodiversity strategy, Nature restoration law, EU taxonomy, CSRD, ESRS, Kunming-Montreal Global Biodiversity Framework and EU Birds and Habitats directive
Frameworks	Google scholar, Scopus, EEA, the EU	frameworks, indicators, environmental indicators, DSPIR, PICABUE, ecosystem service cascade
Indicators	Google scholar, Scopus, Municipalities, legal documents, websites	indicators, ecosystem service indicators, land-use change, land cover, land degradation, emissions, crop production, biodiversity, water regulation, human health, recreational ecosystem services, local climate regulation, food security and species richness

Boolean operators such as “and” and “or” were used. Further, the snowballing method was used to identify additional sources, utilising references from the found articles and reports. Mainly Science and Nature were used and these provide peer-reviewed articles. The selection of articles was further based on the number of citations with a minimum of 20. However, newly published articles from 2024 did not have citations due to recent publication.

3.1.2 Framework & indicator search

To answer RQ 2, different frameworks were reviewed to determine what would be the most suitable. This was done by an initial search of different frameworks which can be seen in Table 3.1. The framework had to have a connection to sustainability and developing indicators from it, which limited the search. Literature, reports and websites containing indicators for ESs and biodiversity were found and utilised since these were established (Peh et al., 2022; Varberg Kommun, 2023; Berghöfer and Schneider, 2015; CBD, 2020).

3.1.3 Interview study

Primary data collection involved qualitative semi-structured interviews with employees at Derome working with subjects related to sustainability. The main aim was to create an understanding of the context of Derome's operations. Semi-structured interviews were chosen to ensure that relevant information and data was generated while allowing flexibility for emerging topics (Kallio et al., 2016). The interview script was created based on the RQs and the initial phase of the literature study, see Appendix A.2 for the interview questions. Five persons with different positions, all related to sustainability, within Derome were interviewed in order to collect a comprehensive image of the knowledge and current work on biodiversity and ESs. The employees that were interviewed were chosen by the Sustainability manager at Derome AB since the person had the most insight into the employees and their knowledge regarding ESs and biodiversity. The interviewees had different positions within the company which are: Project Developer at Derome Bostad, Sustainability Manager at Derome Bostad, Contract Manager at Derome Bostad, Project Manager CSRD at Derome AB and Sustainability Director at Derome AB. Before conducting the interview, the interviewee was asked for permission to record the conversation.

To ensure that information generated during the interview was remembered, the interview was recorded on Microsoft Teams. After the interview, the recording was transcribed using the live transcription tool in Microsoft Teams. To ensure that the transcribing tool worked sufficiently, the transcriptions were read through whilst listening to the recording and possible errors were corrected. Further, the interviews were reviewed and approved by Derome before an analysis of the content was made. The identity of the interviewee was not published to preserve their anonymity. To ensure that the material would not be accessed by a third party, the recording was done on a computer without connection to online storage. Lastly, the interviews were held in Swedish since all participants spoke Swedish and wanted to speak their native language. Since the interviews were held in Swedish, answers or quotes were translated to English by the authors when cited.

The transcribed interviews were analysed thematically with the aim to identify possible patterns or contradictions within the material. The analysis was done through an inductive process where the material was read through simultaneously whilst colour coding to create structure (Braun and Clarke, 2021). All the codes are created depending on the material, finding common subjects and opinions for example ESs, biodiversity, sustainability reporting and building sector. After the transcriptions were coded, and all the codes were placed into created themes with the aim to generate further structure of the material and to identify possible patterns. The themes are broader than the codes, and several codes usually fit into one theme for example transparency about reporting ESs and biodiversity, sustainability reporting demands, difficulties using indicators and the framework and knowledge creation. This step was followed by refinement of the created themes with the aim to collect the information needed from the interviews to answer the research questions. With refinement it is meant that either the theme were changed or that the codes included were changed. All of these steps were iterative, since refinement were done at several occasions.

3.1.4 Personal communication

In addition to interviews, primary data was collected through personal communication. This included visits to Derome's office in Varberg for meetings with supervisors and employees, as well as online meetings and through email. Meetings were conducted where questions about Derome's operations, and about specific information about Derome which could not be found were asked. Several informal interviews, with an ecologist from the municipality of Varberg, provided further insights on how the municipality co-operates with Derome and also about which indicators that are suitable. Written communication like emails containing relevant information e.g. NVIs, EIS's and videos were also utilised in the personal communication.

3.2 The combined framework DPSIR-E

To facilitate creation of indicators for biodiversity and ESs, a framework called DPSIR-E was created by combining the already existing framework, DPSIR, with other frameworks and literature to make it tailored for Derome's purpose (Berghöfer and Schneider, 2015; Brown et al., 2014; Mitchell et al., 1995). DPSIR was created for slightly different purposes previously by the EEA including policy-making. Therefore it was necessary to find articles using DPSIR for developing indicators for measuring ESs and biodiversity. The main criteria for these articles was that DPSIR had to be used for developing environmental indicators to get inspiration for the combined framework. Three additional components; intended actors, purpose and an evaluation step were incorporated into the framework. These steps were included in the frameworks to create further understanding of the context of the situation and to make the indicators suitable.

The key article used for inspiration for incorporating actors, users and receivers, purpose and addressing data collection was by Berghöfer and Schneider (2015). After consideration and deliberation, the decision to make a general framework with a step-by-step guide including guiding questions was made because it makes it more applicable.

3.2.1 Identification of indicators

The aim of DPSIR-E was to develop suitable indicators about ESs and biodiversity. It was a general framework which could be customised to a certain project or operation to develop indicators for ESs and biodiversity. Identifying the indicators using DPSIR-E was done by using the eight steps as illustrated in Figure 3.1.

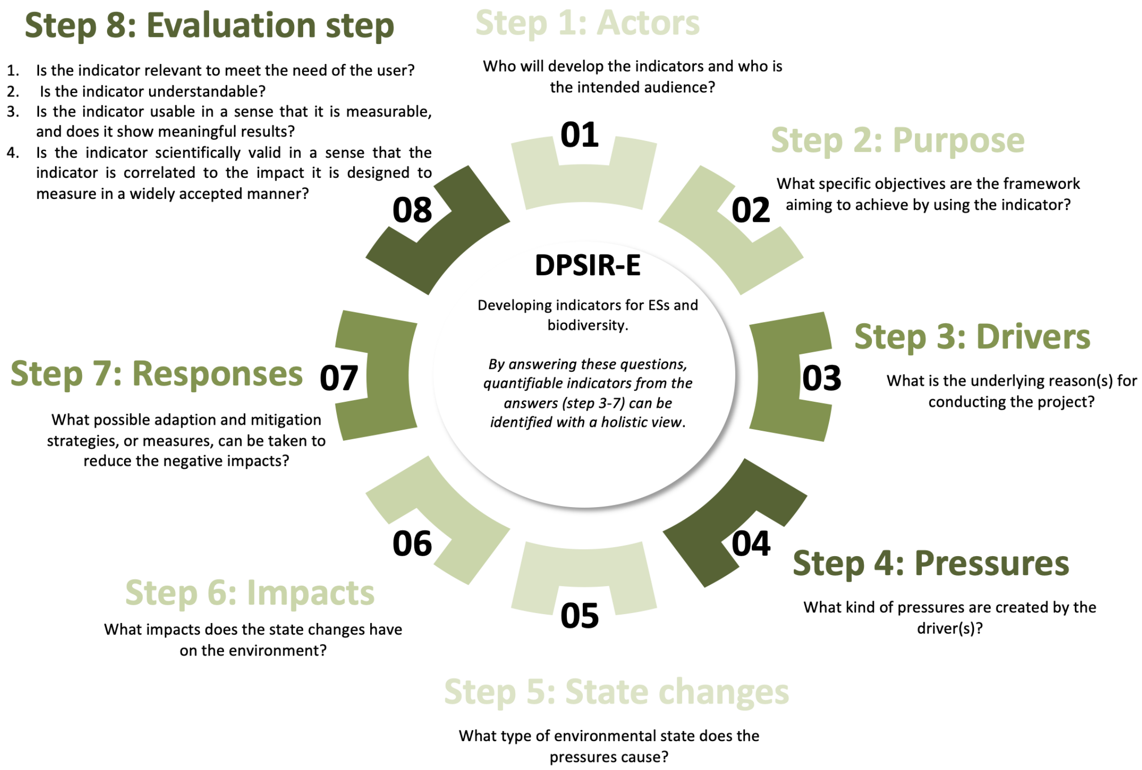


Figure 3.1: *An illustration of the combined framework DPSIR-E's steps, including the guiding questions. Step 3-7 were from the DPSIR framework and were used to identify indicators, and step 1, 2 and 8 were additional steps added to ensure the suitability of the indicators. The illustration made by the authors.*

Brown et al. (2014) was used as a foundation as it highlighted the importance of understanding that "Identifying indicators takes a combination of scientific rigour and creative thinking. Creative thinking may be a surprising skill in this context, but the indicators with the greatest impact are often produced by using and presenting data in novel ways, including combining different kinds of data in ways that may not seem immediately obvious. Scientific rigour is necessary to identify indicators that are conceptually valid and defensible for their purpose.". The indicators created should be practical and not overly demanding in terms of effort on data gathering. What were considered reasonable here was determined by the creator of the indicators which in this case were the authors. By combining the guiding questions presented in 3.1 with the available data and resources for the user, indicators were created (Berghöfer and Schneider, 2015). Iteration was used to identify technically and financially feasible indicators. Developing indicators from every part of the DPSIR was not necessary, since every situation or project was different. It was important to choose the indicators that gave the most important information for the situation (Brown et al., 2014).

Step 1: Actors

The first step included mapping of relevant actors for the situation of which the indicators were intended for. Identification of both the user of the framework and the target audience of the results of the indicators were of importance to set an initial foundation for the indicators (Berghöfer and Schneider, 2015). By using the guiding question *"Who will develop the indicators and who is the intended audience?"*, the direction of the creation of indicators was set.

Step 2: Purpose
Step two addressed the purpose for using the indicators. Different purposes of indicators were, for example, to provide information for decision making, raise public awareness, fortify accountability, reference values for performance, or reporting on progress (Berghöfer and Schneider, 2015). Depending on the purpose, the required information differed, since it considered different situations. The guiding question to answer was *"What specific objectives are the framework aiming to achieve by using the indicator?"*. With this, the purpose and application were determined. When the actors and purpose of the indicators were set, the DPSIR-cycle was used to develop indicators from different entry points.

Step 3: Drivers
The third step included determining the drivers in societies, or patterns which affected the project the indicators were intended for (Berghöfer and Schneider, 2015). *"What is the underlying reason(s) for conducting the project or operation?"* was the question to answer when deciding what drivers were present.

Step 4: Pressures
The drivers, defined in Step 3, created pressures, which was the fourth step in DPSIR-E. In this step, the question *"What kind of pressures are created by the driver(s)?"* was to be answered. Pressures were the consequences of drivers and what they resulted in.

Step 5: State changes
Pressures created a state or condition and referred to the environmental, physical, biological, and chemical conditions in a certain area, which was step five. In the case of DPSIR-E, it referred to environmental states such as ecosystem conditions and functions (Berghöfer and Schneider, 2015). *"What type of environmental state does the pressures cause?"*, was the question to be answered to map the changes in the environment which followed the pressures and drivers.

Step 6: Impacts
The sixth step entailed the impacts from the environmental state changes and included the main effects from the operations. The question which needed to be answered in this step was *"What impacts does the state changes have on the environment?"*.

Step 7: Responses
The seventh step was about societal responses. If negative impacts were found, this step included the possible response to mitigate the effects of them. The question to

be answered was *“What possible adaptation and mitigation strategies, or measures, can be taken to reduce the negative impacts?”*. The responses were often policies or interventions, on a larger scale, to address the underlying issues of the problem. The underlying issues of the problem could be located through iteration of the framework, and the response could be to address drivers, pressures, or state changes again. In addition, Step 7 was closely related to the mitigation hierarchy which was also mentioned in ESRS E4, see Figure 2.5.

With this, the DPSIR-cycle was done, and from these guiding questions potential indicators were found by literature search for the defined drivers, pressures, state change, impacts and responses, see Figure 3.2. There are available resources for finding potential indicators which are scientifically proven, see Table 3.2.

Table 3.2: *Sources which can be used for finding indicators which are scientifically proven.*

Type of literature source	**Authors**	**Organisation**
Toolkit	(Peh et al., 2022)	Bird life, University of Southampton, UN WCMC, Tropical Biology Association, University of Cambridge, rspb, Anglia Ruskin University.
Mapping tool	(Varberg Kommun, 2023)	The municipality of Varberg
Project report	(Berghöfer and Schneider, 2015)	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Helmholtz Zentrum für Umweltforschung (UFZ) Leipzig GmbH, Federal Ministry for the Environment, Nature Conservation, Building and Nuclear sector of the Federal Republic of Germany.
Report	(CBD, 2020)	Convention on Biological Diversity, the UN.

3.2.2 Evaluation of indicators

Step 8: Evaluation

Once the potential indicators were created, the feasibility for the user were important to consider. Therefore **the Evaluation step** was included as a final step in DPSIR-E. Further, it was important to understand that one indicator alone would not provide information regarding ESs and biodiversity at a site. It was the combination of the different indicators that described the condition and the impact of a site regarding ESs and biodiversity. The evaluation step was initially based on the PICABUE methodology (Mitchell et al., 1995). However, this evaluation step contained multiple steps resulting in a complex process for evaluating indicators which motivated researching for another, more suitable evaluation criteria. This was an iterative process which led to several different criteria being analysed. Finally, the four criteria by Brown et al. (2014) were used in the evaluation step of DPSIR-E. To increase the usability, the criteria were made into questions:

1. Is the indicator relevant to meet the needs of the user?
2. Is the indicator understandable?
3. Is the indicator usable in a sense that it is measurable and does it show meaningful results?
4. Is the indicator scientifically valid in a sense that the indicator is correlated to what it is designed to measure in a widely accepted manner? (Brown et al., 2014)

The criteria are explained more in detail in Section 2.5.2.

3.2.3 Suitability of indicators

Suitable indicators, regarding ESs and biodiversity, was identified with the help of the framework. With this, what was meant by the word "suitable" was related to the actors involved with the indicators, the purpose of the indicators and lastly the data collection for the indicators. However, finding suitable indicators for ESs and biodiversity are challenging. It requires a comprehensive understanding of the situation, project or operation and choosing a suitable indicators from the potential ones (Berghöfer and Schneider, 2015). What was considered suitable for Göinge by and Göingegården was determined by the interviews, personal communication with the employees in combination with literature.

3.2.4 Tracking changes

After identifying, evaluating, and measuring the indicators, it was important to track changes over time. When the indicators were listed in a table together with their unit, there were some columns that could be added to track changes to them. Depending on the operation for which these indicators were developed, it was crucial to observe the changes within each indicator in the table where they were presented. Preserving existing nature areas was crucial for maintaining ESs and biodiversity. By conserving these ecosystems, we ensured that their complex balance and functionality remained intact. In contrast, creating entirely new nature areas was time consuming since it takes a long period of time for ecosystems to establish and reach their full potential (T. Barrett, personal communication, 10 April, 2024). Therefore, prioritising the preservation of existing nature areas was essential for maximising the benefits of ESs and biodiversity. With this, the table containing the ESs and biodiversity indicators was created to include the columns: initial, maintained, added, removed, and final value. This enabled visualisation of how much of the initial value was kept, what was removed, and if any value was created. A simple scoring system was included based on the impact that operations performed had on ESs and biodiversity. The scoring system ranged between - to +. If the initial value was better than the final value, the score was be "-" and if the initial value was worse than the final, the score was be "+". Regarding what was better or worse depended on the individual indicator, and it had to be supported by literature.

3.3 Case study: Göinge by and Göingegården

A case study, Göinge by and Göingegården, was provided to illustrate an example of the process of creating indicators. Examples of metrics regarding the created indicators are provided for Göinge by. The reason for only providing metrics from Göinge by is time constraints and data availability. Göinge by and Göingegården was chosen as a case study due to many reasons. First, the area consisted of both a construction site and a finished residential area which made it a good example to track changes. Second, contacts at Derome had been actively engaged in the project, offering valuable insights and experiences that could be applied. Lastly, the location of the site in Varberg facilitated a study visit, enabling direct observation of the area.

3.3.1 Data management of indicators for Göinge by and Göingegården

The data management was done according to the iterative process described in Figure 3.2.

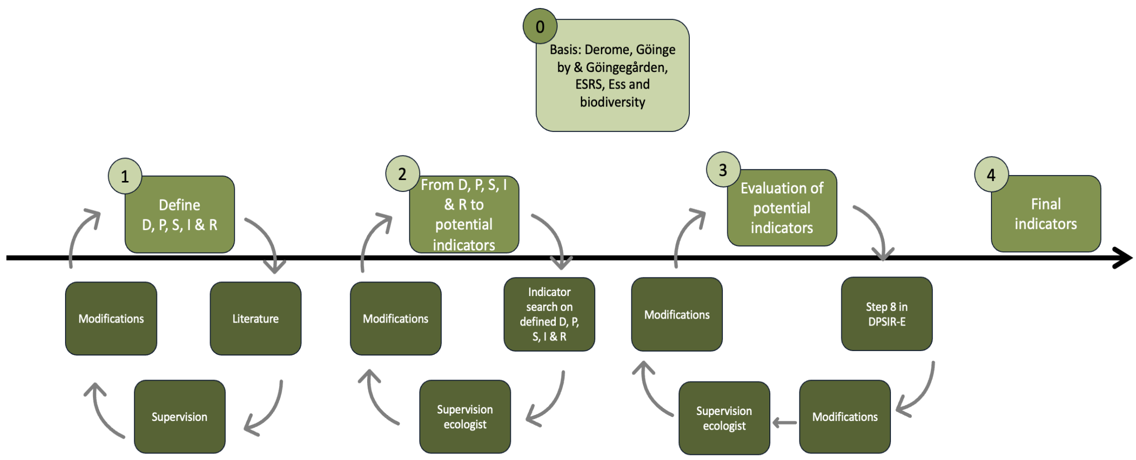


Figure 3.2: *The iterative process of finding suitable indicators with the combined framework DPSIR-E. Illustration made by the authors.*

The initial step in the process of developing site specific indicators for Göinge by and Göingegården, was **step 0** which included gathering knowledge regarding the scope, actors and purpose of the indicators. **Step 1** included defining the different components in DPSIR which was done through the literature search. **Step 2** was where the potential indicators are created by a literature search. Further, supervision sessions with an ecologist from the municipality of Varberg were conducted to get more insight and relevant information from someone local with relevant knowledge about indicators for ESs and biodiversity. This led to modification of the potential indicators. **Step 3** in the process of developing indicators included the evaluation of the created indicator derived in the previous step. The evaluation was based on the criteria mentioned in Brown et al. (2014). This step included an additional supervision with an ecologist from the municipality which led to modification. **Step 4** was the last step of the data management where the indicators were finalised.

3.4 Delimitations

This master's thesis focused on the building and construction sector in relation to reporting according to CSRD. More specifically, Derome and their aim to measure ESs and biodiversity to enable sustainability reporting aligned with ESRS E4 were the main focus. Although, some more delimitations were made which are explained in the sections below.

3.4.1 Suitable indicators

One delimitation is the definition of suitable. Since the word can imply different things, the decision to define it with the sub-questions to RQ 2 was made. With this, other definitions of the word suitable was not included. This was done to enable the concept of suitability into the framework and eventually, into the identification of suitable indicators.

3.4.2 CSRD & ESRS E4

A delimitation was made to ESRS E4 and CSRD because Derome required support with CSRD in combination with ESs and biodiversity. Additionally, the indicators developed were tailored only to Göinge by and Göingegården because it served as an example in the case study of Derome. The results are not to be categorised as a finished sustainability report according to CSRD, but delivers a framework for developing indicators for measuring ESs and biodiversity which in turn enables reporting according to CSRD. Furthermore, while CSRD includes reporting the whole value chain of the company, the indicators developed were site-specific. Hence, the system boundaries of CSRD are wider, but the indicators developed were site-specific and aligned with CSRD reporting demands to the greatest extent possible.

3.4.3 Scope & terminology

The focus was on existing literature regarding indicators for measuring ESs and biodiversity, in combination with different types of reporting legislation and permit processes regarding the construction of residential buildings. Furthermore, although the impacts from extraction and processing of raw material were likely high, this was not considered. Further, the term ESs was used due since CSRD and other legal directives are using that definition and not NCP.

3.4.4 Geographical scope & land-use change

The geographical scope was within the area that Derome operates in Sweden, specifically from Gothenburg down to the northern parts of Skåne (A. Carlsson, personal communication, 23 February 2024). The focal point was land-use and land-use change (LUC) during the construction stage of residential buildings and how it affects ESs and biodiversity. The calculations for the initial values for some of the indicators at Göinge by are provided in Section 4.3.10. For a full description of the calculations see Appendix A.7. The reason for only providing a quantification of the indicators for Göinge by and not Göingegården was the lack of data.

4
Results

This section presents the results from the application of ESRS E4 to Derome, Derome's usage of the framework and indicators and lastly the application of the framework on Derome's operations at Göinge by and Göingegården. Suitable indicators for Göinge by and Göingegården aligned with ESRS E4 regarding their use of land in the construction stage, are identified.

4.1 Application of ESRS E4 to Derome

The results of the interview study showed four themes relating to CSRD and reporting on ESs and biodiversity, as well as the desired approach to reporting from Derome's point of view. The four themes included: legal requirements, transparency, marketing and requirements from authorities.

4.1.1 Legal requirements: ESRS E4

According to interviewees, the legal requirements regarding reporting on ESs and biodiversity entails CSRD, more specifically ESRS E4. The five interviewees said that Derome was in the initial phase of CSRD reporting. In other words, preparatory work was undertaken towards reporting, which included mapping the requirements of CSRD and making initial analyses to understand what and how to report. Further, according to the interviewees there were several opportunities and some barriers for Derome related to sustainability reporting.

To be able to report on biodiversity and ecosystems according to ESRS E4, measuring and monitoring Derome's impact on biodiversity and ecosystems needs to be aligned with their business plans and their operations with respect to the protection and restoration of biodiversity and ecosystems (EFRAG, 2023). Furthermore, knowledge of the current situation and mitigation actions regarding biodiversity and ecosystems are needed. One way to do this is by using indicators for ESs and biodiversity for site-specific operations. By tracking and finding trends with the indicators, it enables reporting and aligns a company's business plans and operations to restore and protect biodiversity and ecosystems.

4.1.2 Transparency & marketing

Another purpose of CSRD reporting, according to the interviewees, was to improve their ability to display their impact on ESs and biodiversity. Throughout the interviews, transparency regarding Derome's impacts from their activities was emphasised as important when reporting on ESs and biodiversity. Four interviewees highlighted the importance of transparency in sustainability reporting.

"... so it was clear that we did have an impact on how we managed them, the resources or affected the land, of course. In order to report on both and have transparency earlier we wanted to show, and be open about it too. Of course, we would be open even if we did something that was bad. Then you got transparency as well as transparency when it was good." - Sustainability Manager at Derome Bostad

All interviewees were aware that Derome's operations have an impact on the environment due to their exploitation of land. How they manage their operations is therefore of importance. The Project Manager for CSRD at Derome AB reflected on the company's positive and negative impacts, and the opportunities to improve and have a positive impact later on. Further, the Project Developer at Derome Bostad expressed an interest in showing both what was lost and gained during the construction of residential areas.

Another emerging theme in the interviews was the use of the results from the indicators for marketing purposes. According to the interviewees, Derome already has a sustainable approach within the construction and building sector, which they aim to continue. Driving forces behind the use of indicators, to measure and report on, are to improve them as a company and to compare with competing companies. Additionally, they aim to show customers what they do well and build their brand on a good reputation. These indicators could also help clarify what Derome is doing, and build Derome as a sustainable brand. Two interviewees discussed the company's desire to lead in sustainability within the construction and building sector.

"But also that like this, competitors and other stakeholders kind of look towards our direction to see how we're doing, that one can be a role model and a leader, that's what I think." - Project Manager for CSRD at Derome AB

4.1.3 Requirements from local authorities

Other requirements of CSRD reporting included certain legal obligations affecting Derome's operations. According to the interviewees, in order to obtain permission to build, despite the presence of biotope protection areas at the construction site, Derome has to apply for permission to the County Administrative Board. If permission is granted, compensation measures will be taken if proven necessary.

There are further requirements outlined in the detailed development plan concerning what should be preserved or altered. According to the Contract Manager at Derome Bostad, they need to report what is done for biodiversity. External entities, often the municipality in the area, regulates what is permitted on a specific area which is covered by a detailed development plan. This means that Derome has to adapt to what is stated in the detailed development plan, according to the interviewees. For example, Derome is only permitted to place sedum roofs, a type of green roof, on their carports to increase the green factor if it is stated in the detailed development plan.

“So it was a challenge in itself that we didn’t always have complete control over the impact we had. Instead, it was somewhat the municipalities that set the regulations for us.” - Sustainability Manager at Derome Bostad.

4.2 Evaluation of indicators

In the evaluation the indicators were evaluated based on their suitability. The process and criteria to identify what suitable was started with interviews with the intended actors to establish their intended need for the indicators, to establish that they made sense and were measurable.

4.2.1 The actors’ intended purpose of the indicators

The word “suitable” was addressed through asking about the usage of the combined framework to develop indicators at Derome, and how that process could look like. What it entailed for them as a company to use the framework, including the data collection for the indicators were discussed.

The interviewees were asked how the framework and indicators might have helped Derome with their work regarding ESs and biodiversity, but also if there were any possibilities or difficulties. One of the interviewees mentioned that common ground about ESs and biodiversity needs to be found within the sector, and to find a few focus areas for Derome. This would narrow the scope, making it manageable for Derome to implement it in their work. The Sustainability Manager at Derome Bostad also mentioned that indicators might help to find common ground in these types of questions. Also, a base line can be found which can help Derome to improve in these areas.

Derome had no previous experience of ESs and biodiversity indicators and was not using any tools but perceived working with indicators as an opportunity to learn. The interviewees recognised a lack of knowledge and understanding of ESs and biodiversity and perceived the concepts as quite difficult to grasp. The employees’ unfamiliarity with ESs and biodiversity was compared to the average citizen who might not know what biodiversity was or what it entailed.

“Lack of knowledge perhaps to the extent that internal training on biodiversity and ecosystem services might be needed, I believe... Yes, I would say the challenges there probably lie in our, well, our own knowledge in some way. Who should or can do this calculation? Or if one should understand it. There may be a need for internal training on biodiversity and ecosystem services.” - Project Developer at Derome Bostad

The interviewees thought that working with ESs and biodiversity would be challenging in the beginning. Working with indicators on ESs and biodiversity was perceived as an opportunity and there was a belief that it was possible to close the knowledge gap and create knowledge in the company as well as in the construction industry. Starting with some important indicators and over time developing the work.

During the interviews, the employees at Derome could identify several purposes for the indicators for ESs and biodiversity such as creating an organised way to include ESs and Biodiversity in their overall environmental work and in communication. Measurable and quantifiable indicators were emphasised to be able to create a reference value and to track changes over time which was important according to the Contract Manager who thought “it was encouraging to know when the company was improving or not”. Many of the interviewees agreed with the Contract manager, that metrics were a prerequisite to be able to identify areas to improve and drive the sustainability work at Derome forward.

“Then we also have an opportunity to set goals for the kind of progress we want to make and how much we want to improve, and so on. So I think we will be able to gather the baseline level very effectively.” - Sustainability Manager at Derome Bostad.

Quantified indicators were believed to also be important for communication and building awareness within the company, as trends created by introducing indicators for ESs and biodiversity could be presented to employees. Such awareness in the company would help Derome to improve even more, said the Project Manager for CSRD at Derome AB.

Another use of the indicators was for reporting, both for reporting on the construction site’s impact on ecosystems and biodiversity, and for CSRD. The Project Developer at Derome Bostad discussed the possibility of Derome using indicators as arguments for gaining permission to use a specific land for construction of residential areas. It would then be possible to report the impacts at a construction site but also what and how their activities could create additional natural value there.

“And we will demonstrate that yes, this will be lost, but we can also create this, so that one can see it with clear numbers in some way. It will become an important issue for example in politics going forward so that they will approve or that officials in the municipalities will approve construction of houses in an area.” - Project Developer at Derome Bostad

Several interviewees recognized that collecting data on ESs and biodiversity was a reason to be able to address the aim of CSRD with transparent and open reporting. The collection of data on ESs and biodiversity data was further perceived as an action to increase awareness of the issue in the company which would make employees more engaged in the issue of ESs, ecosystems and biodiversity and the company’s environmental work.

4.2.2 Understandable, measurable and useful indicators

Indicators are often used to monitor development over time and any environmental issue followed up needs a specific set of indicators (Meadows, 1998). Identifying indicators for ESs and biodiversity requires comprehensive understanding of the situation, project or operation (Brown et al., 2014). During the interviews, a framework was discussed as a tool for long term data collection and evaluation.

A reaction on a framework was the importance to find “common ground” both in the company and in the industry. An interviewee was concerned about the common ground in the construction industry to be able to find a few focus areas for Derome. The Sustainability Manager at Derome Bostad pointed out that indicators might help the company to find common ground in these types of issues. To have a base line would be helpful for Derome to improve in these areas. The Sustainability Manager at Derome Bostad discussed site specific nature of the indicators and the difficulties to develop a framework that could be used in the whole Derome Group. The company included multiple business areas with a focus on different parts of the construction phase. In addition to the discussion of the framework there was a discussion important to the interviewees about an extra workload for the users. It concluded that the implementation would have a slow start.

4.3 Application of DPSIR-E at Göinge by and Göingegården

By using the DPSIR-E framework step-wise, suitable indicators were identified at Derome’s construction site Göinge by and Göingegården located in Varberg, where the results can be used for reporting according to CSRD.

4.3.1 Step 1: Actors

Derome aims to use these indicators to help with CSRD reporting, but also to use them internally in the company. Derome was the user of the framework and the receivers of the indicator results were Derome and the stakeholders contributing to the sustainability report. Other relevant actors could be municipalities and the county administration board where their operations take place.

4.3.2 Step 2: Purpose

The objectives of creating the indicators from the framework were to use the results and initiate reporting on ESs and biodiversity for communication to CSRD, improving the internal environmental work and maintain their leading position in the industry (A. Carlsson, personal communication, 23 February, 2024). It was agreed that the indicators should include measures showing the effects on ESs and biodiversity from the development as agricultural land was transformed into residential areas with the aim of minimising their impact. Further, it was understood that the indicators needed to be adjusted to the CSRD reporting and ESRS E4. With all of this in mind, the driver, pressures, state changes, impacts and responses were defined, see Figure 4.1, and details on how these are defined is presented in the next five subsections.

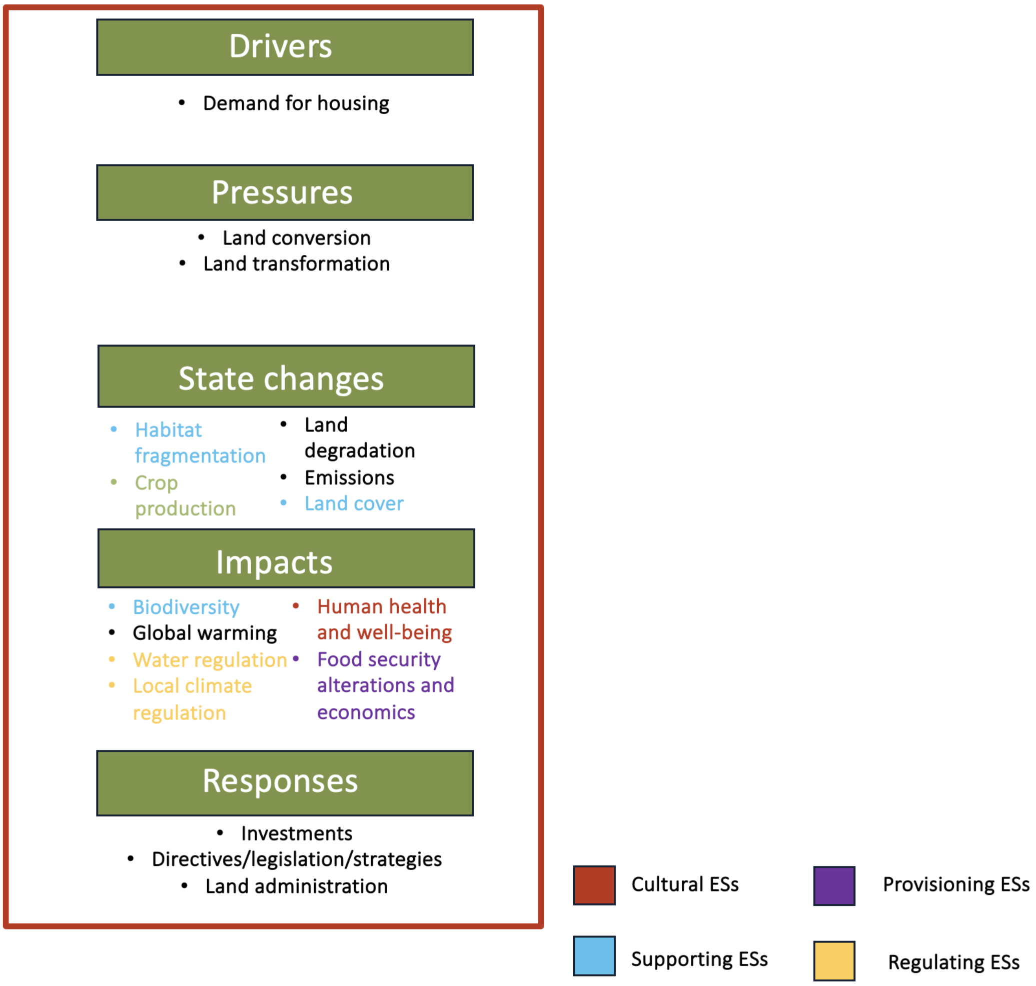


Figure 4.1: *The defined driver, pressures, state changes, impacts and responses for Göinge by and Göingegården. The colour coding refers to the type of ESs. Illustration is made by the authors.*

4.3.3 Step 3: Drivers

The driver in this case is determined to **Demand for housing** since it is the underlying reason to why Derome's operations are occurring. According to A. Carlsson the demand for housing is the most important driving force for Derome as a company (A. Carlsson, personal communication, 23 February, 2024). At the time, the demand for residential buildings in Sweden was high as there was a higher demand for residential housing than supply of new residential living accommodation (Boverket, 2023a; SCB, 2024). Other potential drivers were discussed, however it was concluded that the commonality was the demand for housing.

4.3.4 Step 4: Pressures

LUC is the pressure identified which was divided into **Land transformation** and **Land management**. The demand for housing (driver) caused LUC at the construction site as land is converted from agricultural land to residential area. The choice of two different pressures for LUC was done since the effects were different and would occur at different temporal stages. Land transformation described the construction process where the land was transformed from e.g. agricultural land into land for residential housing (IPBES, nda). Land management described how the land was used and administered after construction was finished (IPBES, nda).

4.3.5 Step 5: State changes

The environmental state which the pressures cause in this case are: Habitat fragmentation, Land cover change, Land degradation, Emissions and Alterations in crop production at Göinge by and Göingegården. These represent consequences of the identified pressures.

At Göinge by and Göingegården there will be **Habitat fragmentation** since natural areas will be divided due to e.g. building residential areas. Habitat fragmentation is the process where a land area that has been connected previously is divided resulting in a disconnected habitat. The fragmentation can be a result of both natural activities, such as fires, but it can also be driven by societal activities such as urbanisation (IPBES, nda). The effects of habitat fragmentation may result in biodiversity decline depending on the area's proximity to the urbanized area and the mean size of the species natural habitats (Li et al., 2022).

Land cover was defined in ESRS E4 but could be explained as impacts on ESs and biodiversity by habitat modification caused by human activities. In ESRS E4 as "... the physical representation of the drivers habitat modification and industrial and domestic activities" (EFRAG, 2023). The change of land cover is further defined as "..the man-made or natural change of the physical properties of Earth's surface at a specific location" (EFRAG, 2023).

When turning the area to a residential area, **Land degradation**, will occur. It is one of the most severe environmental problems for society since the land provides water regulating, food provisioning and climate regulating services (Prăvălie, 2021). Further, land ensures stability of the ecosystem through securing habitats important for biodiversity. Regarding impact on soil and land, ESRS E4 mentions e.g. land degradation, desertification and soil sealing as areas that need to be addressed. In the current case soil sealing includes both sealing of the surface and compaction was of more relevance. "Surface sealing" and "compaction" is considered to be of relevance here. However, the two definitions are combined into "soil sealing" as it includes both sealing of the surface and compaction (Tobias et al., 2018).

Emissions, or air emissions according to Eurostat (n.d.), includes both GreenHouse Gases (GHG) and air pollutants contributing to different environmental problems and can be harmful to people, flora and fauna according to Eurostat (n.d.). GHG includes in total seven gases which contribute to climate change, while air pollutants are harmful to human health and biodiversity (Eurostat, nd). Further, findings of the Intergovernmental Panel on Climate Change (IPCC) shows that around 12% of the worldwide GHG is connected to LUC, including deforestation, and since the relationship between LUC and emissions is complex the number might be even greater. The number could be higher since the relationship between LUC and emissions was described as complex (Wang, 2024).

Crop production can be described as the lost land previously used in food production. Food production is in the Swedish Environmental Code described as a national interest and implies that agricultural land is preserved which is in conflict with societal interests where the land can be used for construction of residential housing (SFS 1998:808, 3 ch. 4 §). The shift from agriculture practices into another land use may lead to irreversible environmental effects locally and to decreased control over the food supply within a country (Slätmo, 2017). However, this land can be used for construction of residential housing since this is considered to be of substantial societal interest.

4.3.6 Step 6: Impacts

The defined impacts at Göinge by and Göingegården were Biodiversity, Water regulation, Human health and well-beeing, Global warming, Local climate regulation and Food security alterations and economic impacts. These impacts represent the effects from state changes.

Biodiversity is a defined impact in DPSIR-E and is also a supporting ES. This impact includes several aspects of biodiversity according to CBD's (2006) definition and is a consequence of state changes in habitat fragmentation, land cover and soil properties.

Water regulation is defined here as the regulating ESs and includes delaying, filtering, purification of water from pollutants, preventing floods, erosion and drought (Varberg Kommun, 2023). The change of land cover like soil sealing will affect flooding. Water runoff occurs when the soil lack the ability to absorb excess water and instead the water flows across surfaces into nearby water bodies (National Geographic, 2023).

Human health and well-being are described as the physical and mental health of humans and is affected mainly by the state changes emissions and land cover (Aseel et al., 2021). Human well-being is dependent on the continuation of several ESs such as land cover and water regulation as they influence the physical properties of nature where humans often find recreational opportunities for physical activity and cultural values (Varberg Kommun, 2023). Further, the human well-being can be defined as in the article by Xu et al. (2016) "human experiences, including the basic materials for human lives, freedom of choice, health, good social relations, a sense of 'cultural identity' and security." and it is dependent on the continuation of several ESs.

Global warming is a consequence of changes in emissions and of land cover. Important to note is that global warming affects other impact categories e.g. biodiversity, human health, deforestation and food security (Abbass et al., 2022). The ESs Air quality regulation mitigates air pollution, also relates to global warming (Matos et al., 2019). Green areas and especially trees are important to the regulation of air quality, pollutants in the air, to humans' physical a health and other species' health as well.

Local climate regulation is a regulating ESs which includes temperature regulation and land cover changes caused mainly by urbanisation (Brown et al., 2014). Temperature regulation occurs through vegetation, green areas and trees, and is used in cities to moderate the temperature according to Brown et al. (2014). Change in land cover includes the change of land for example soil sealing (compaction) in the context of water run-off but also desertification of fertile land. Both of these are included in the ESRS E4.

Food security alterations and economic impacts was included as an important impact, since agricultural land and crop production provides ESs. An altered purpose of agricultural land creates a loss of potential yield, food security and economic consequences (Varberg Kommun, 2023).

4.3.7 Step 7: Responses

The impacts of construction activities were represented by **Investments**, **Directives**, **Legislation**, **Strategies** and **Land administration**. The Swedish Environmental Code and the Swedish Planning and Building act are both examples of national legislation that has the aim to regulate what type of activity is permitted and where it should be permitted (SFS 1998:808, 1999; SFS 2010:900, 2010a). With acknowledging the impacts of the construction, areas of importance and improvement can be identified resulting in compensation or improvement actions (EEA, 1999). ESRS E4 specifically mentions that one of the aims with the Standard is to "... any actions taken, and the result of such actions, to prevent or mitigate material negative actual or potential impacts and to protect and restore biodiversity and ecosystems, and to address risks and opportunities" (EFRAG, 2023).

4.3.8 Potential indicators for Göinge by and Göingegården

The result of creating indicators with the DPSIR-E framework resulted in 26 potential indicators, see Figure 4.1. All indicators are derived from the defined drivers, pressures, state changes, impacts and responses in the previous section which are specific for Göinge by and Göingegården.

Table 4.1: *The 26 potential indicators for Göinge by and Göingegården. Cultural ESs are in red, supporting ESs are in blue, provisioning ESs are in purple and regulating ESs are in yellow.*

Indicators	ESs	Unit	Initial	Maintained	Added	Removed	Final	Score	Comments
Species richness	🔵	no. of species							ESRS E4
Pollination potential	🟡	% (RPP)							ESRS E4
Biotope protection area	🔵	no. of different biotopes no. of each biotope							Related to ESRS E4
Red listed species	🔵	no. of species							ESRS E4
Threatened species	🔵	no. of species							ESRS E4
Invasive alien species	-	no. of species							ESRS E4
Protected area coverage	🔵	% (protected area/total area)							ESRS E4
Soil sealing	-	% (paved area/total area)							ESRS E4
Emissions	-	CO2-eq.							ESRS E1
Air pollutants absorption rate	🟡	kg/year							ESRS E4
Land conversion rate	-	hectar/year							ESRS E4
Water contamination level	-	g/L							Related to ESRS E4
Infiltration trench	🟡	meter							ESRS E3
Retention basin	🟡	% (area of basin/drainage basin)							ESRS E3
Runoff avoided	🟡	L							ESRS E3
Rainfall intercepted	🟡	L							Related to ESRS E4
Green space	🔵	%							ESRS E4
Green space factor	🔵	%							ESRS E4
Canopy cover	🔵	%							ESRS E4
Green space accessibility	🔴	metre							Related to ESRS E4
Active transportation accessibility	🔴	km/cap							Related to ESRS E4
Community benefits	🔴	no.of different sites							Related to ESRS E4
Educational sites	🔴	no. of schools and educational sites							Related to ESRS E4
Temperature regulation	🟡	°C							Related to ESRS E4
Rate loss of potential crop yield	🟣	tonnes/year							Related to ESRS E4
Agricultural land valuation	-	SEK/hectar							Related to ESRS E4

Biodiversity is a defined impact from the DPSIR-cycle, see Figure 4.1, of which seven different indicators are derived from it. The indicators were: Species richness, Pollination potential, Biotope protection areas, Red listed species, Threatened species, Invasive alien species and Protected area coverage. According to IPBES (n.d.), **Species richness** is defined as “The number of species within a given sample, community, or area.”. This indicator is included since it is a well-known biodiversity indicator. The measurement of species richness is performed by quantifying the total number of species within that area. In the table’s scoring system, the higher final value represents a better value. Prior to the project of Göinge by and Göingegården, Varberg municipality requested a NVI, see Figure 2.8 which can be used for the measurements.

Pollination potential is a regulating ESs that ensures plant growth which in turn enables life on Earth to sustain (IPBES, 2016). To measure different ESs in Europe, the Ecosystem Service Mapping Tool (ESTIMAP) was created in 2013 by the EU (Zulian et al., 2013). The model presented in ESTIMAP entails information of the different contribution to pollinators that different types of land might have. The unit of Relative Pollination Potential (RPP) is percentage. In the scoring system in the table, the higher final value the better. A flowchart regarding the calculation of RPP can be seen in Appendix A.4.

Biotope protection area are areas of significant importance for biodiversity and was included in the NVIs and should therefore be included. To generate detailed information on the effects on biodiversity different measures can be used. The unit used for this metric is the total number of biotopes and the number of different types of biotopes. If only the number of biotope protection areas were to be presented, the variation within the area would not be visible. In the scoring system in the table, the higher final values of both, the better.

Next, Red listed species, Threatened species and Invasive alien species were included in ESRS E4 (EFRAG, 2023). **Red listed species** is included as an indicator with reference to the IUCN Red list. It has the unit: number of species. In the scoring system in the table, the lower the final value the better. **Threatened species** are a type of classification in the IUCN Red list, and is included as an indicator as well. As an indicator in this context, the number of species is the unit used. In the scoring system in the table, the lower the final value the better. **Invasive alien species** are species which are relocated by humans and are spreading quickly and cause severe impacts on the new environment (Naturvårdsverket, nda). These species are a huge threat to biodiversity and the ecosystems, and could potentially involve costs for society when destroying the environment. To keep track of the invasive alien species in the area, the indicator is made with the unit of number of species. In the scoring system in the table, the lower the final value the better. Lastly, in Sweden there are approximately 400 invasive alien species who pose a threat (Naturvårdsverket, nda). To generate data regarding invasive alien species at Göinge by and Göingegården, direct measures are needed since there is a lack of data regarding this in the NVI and EIA.

Protected area coverage is listed in ESRS E4 and includes Protected areas include for example nature reserves, national parks, Natura 2000, biotope protection areas, animal and plant protection areas, shoreline protection areas and water protection areas (Länsstyrelsen, nd; EFRAG, 2023). The unit for this indicator is the area of protected land/total area, which makes it a percentage. In the scoring system in the table, the higher final value the better. Data can be found in the format of a map on Naturvårdsverket's website and map tool for protected nature in Sweden (Naturvårdsverket, ndc). The areas that have been given a red classification, see Figure 2.8, are already protected by the shoreline protection regulation and are likely not to be exploited.. In general, the biotope protection areas or objects were located where ongoing or will be construction of residential housing. If there were risks of the operation disturbed or destroyed these objects, permission from the county administration board was required.

Soil sealing connected to land cover, see Figure 4.1, was used in ESRS E4 (EFRAG, 2023). The smaller the area of compaction, the better (Peh et al., 2022). Similarly, in the scoring system in the table, the lower the final value the better. There are several types of compaction and in this case all paved areas i.e. roads, parking lots and buildings are included. The unit for this indicator is in percentage and the formula is area of paved area/total area to get an estimation of the amount of land being compacted.

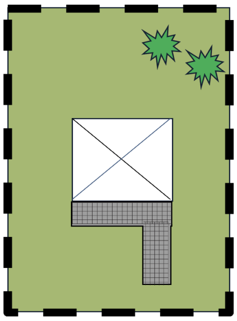
Emissions, belongs to the impact category Global warming, see Figure 4.1. This is measured within a company for other reporting, however the connection to ESs and biodiversity needed to be clarified. The chosen unit for this impact is kg CO_2-eq and the used index is Global Warming Potential (GWP). In the scoring system in the table, the lower the final value the better.

Air pollutants absorption rate is mostly regulated by trees, hence a regulation ESs. Pollution is included in ESRS E4 as an important driver for biodiversity loss (EFRAG, 2023). It is from the defined impact Local climate regulation, see Figure 4.1. The higher the number of trees, the more air pollutants will be absorbed. Measuring the exact uptake is a complicated process, but estimations can be done (Brown et al., 2014). The unit is kg/year, and instructions on how to calculate this indicator are stated in Appendix A.5. In the scoring system in the table, the lower the final value the better. Data on carbon monoxide, ozone, nitrogen dioxide, CO_2-eq., sulphur dioxide and PM2.5 uptake is calculated.

LUC was the one of the defined pressures in DPSIR-E, see Figure 4.1, and the indicator developed from this is **Land conversion rate** with the chosen unit of hectares/year. According to Peh et al. (2022) Google Earth can be used to estimate types and amounts of habitats that have been converted into something else by assessing what was preserved and not. In the scoring system in the table, the lower the final value the better. Water pollution is the next impact category, and the indicator **Water contamination level** is determined. This is related to flooding due to soil sealing, and a proposed unit to measure the polluted water was concentration in mg of pollutants/L of water. In the scoring system in the table, the lower the final value the better.

For the defined impact category Water regulation, see Figure 4.1, four indicators were developed: Infiltration trench, Retention basins, Runoff avoided and Rainfall intercepted. To protect against floods, extreme rainfall and even temperature regulation water regulation in urban areas were important (Iojă et al., 2021). An **Infiltration trench** purifies and slows down the velocity of storm water and rainfall and it is similar to a canal but covered by vegetation of grass (VISS, 2020a). The unit for measuring infiltration trenches is metres. In the scoring system in the table, the higher the final value the better. **Retention basins** enables water purification, slows down the speed of the storm water, contributing to ESs and may increase biodiversity. Generally the larger the retention basin in relation to its uptake area, the better (VISS, 2020b). The unit is therefore in percentage because it is the area of basin in relation to drainage basin. Accordingly, in the scoring system in the table, the higher final value the better. Both Infiltration trenches and Retention basins can be measured using Google Earth (Peh et al., 2022). **Runoff avoided** is the amount of rainwater that reaches the ground and does not stay on the surface. Instead, the water is taken up by the tree roots and stored in the ground resulting in less risk of flooding. **Rainfall intercepted** is the amount of rainwater that reaches the leaves and is evaporated into the air again (I-Tree Eco, nda). Both the amount of runoff that is avoided and rainfall intercepted are measured in L and in the scoring system in the table, the higher the final values the better. Regarding the data and calculations, they are the same as for Air Pollutants Absorption Rate and can be found in Appendix A.5.

From the defined state change Land cover, see Figure 4.1, urban green space is included and is defined as both trees and green areas. Forest cover is included in ESRS E4, which is similar to urban green space (EFRAG, 2023). Green space can be calculated in two different ways here; **Green space** or **Green space factor**. The calculation is the area of green space/total area, where the higher number generated the better, and this calculation is in percentage. To measure the green space area in the total area of the construction site it is possible to use Google Earth (Peh et al., 2022). Further, the green space factor represents the relationship between the "eco-efficient" area and the entire area (Boverket, 2020). It helps determine the percentage of functional green areas compared to hardened surfaces. Functional green areas contain permeable surfaces as well as areas with trees, lawns, or green roofs. The specifics and examples of the calculations needed are to be found here (Stockholm Stad, 2021). For an illustration, see Figure 4.2.



Type of space	Value	m²	Eco effective area
Land and vegetation	0,4	30	12
Bushes and solitary bushes	0,4	3	1,2
Roof, compact	0	40	0
Permeable hard surface	0,25	10	2,5
Sum		83	15,7

Figure 4.2: *Green space factor and how to calculate it, with an example. The Green space factor in this case is 15,7/83=0,19 (Boverket, 2020). Figure translated and modified from Boverket (2020).*

The indicator **Canopy cover** was derived from both the impact Local climate regulation but also Human health and well-being, see Figure 4.1. Trees often invite people to spend more time outdoors and which increases their social activities. Canopy cover is calculated by analysing aerial photos and the measurement is an estimation that illustrates the ratio between the total ground area and the coverage of trees (ESRI, nd). Boverket has created a map including canopy cover which can be used to generate data for this indicator (Boverket, 2023c) and an example can be found in Figure 4.3. The higher final value the better in the scoring system in the table for all the indicators for Urban green space.

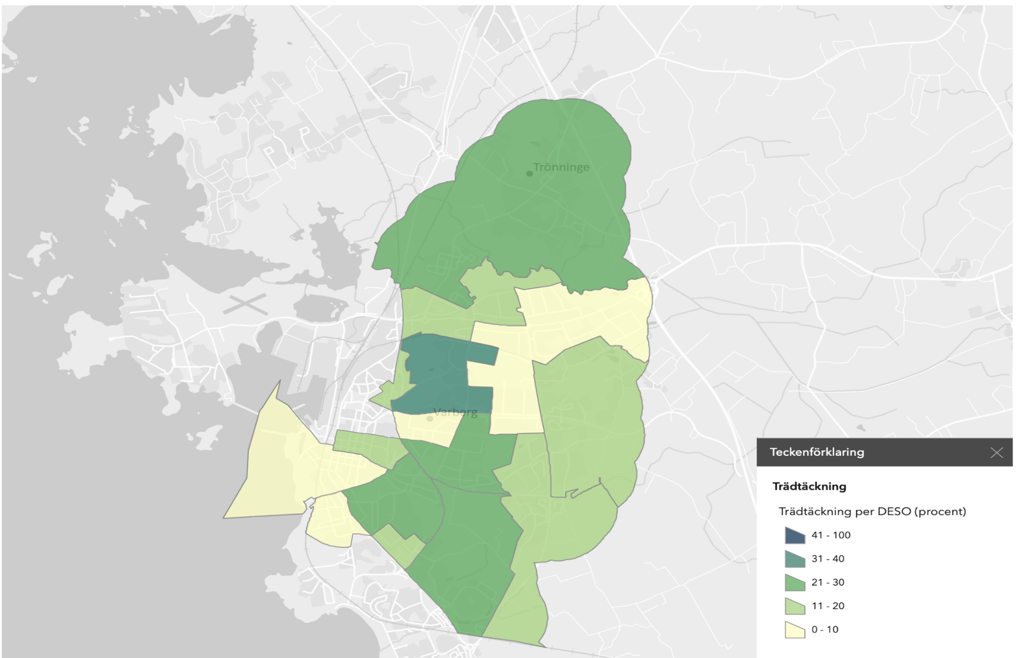


Figure 4.3: *The canopy cover in Varberg. The darker the colour, the more dense the canopy cover. Illustration made with data and information from Boverket (n.d.).*

The defined impact category Human health and well-being, see Figure 4.1, it produced four indicators: Green space accessibility, Active transportation accessibility, Community benefits and Educational sites. These are included since ESRS E4 mentions ESs, and the cultural ESs are relevant when building residential areas (EFRAG, 2023).

Green space accessibility describes the presence of green spaces within residential areas which compensates for the absence of nearby parks by providing residents with similar opportunities for outdoor recreation and leisure activities close to their homes and is a cultural ESs (Mao et al., 2020). It is measured in metres to the nearest green area and is calculated with the help of Google Earth, and it is the residential building which is the furthest from a green space. In Sweden there is a “Urban green structure rule” called “3-30-300”, which is guideline values for urban green spaces (Region Skåne, 2023). The number three stands for at least 3 residential-proximate trees, 30 at least 30% canopy coverage in the neighbourhood, and a maximum of 300 metres between residences and green areas. With this, a reference value of maximum 300 metres from each residential house there should be defined as a green area is defined. **Active transportation accessibility** was cultural ESs important in the area of recreation (Brown et al., 2014).). The measure in km/capita referred to the number of pathway km for biking and walking per capita. The measure reflects the population size and the number of pathways available per person.

Community benefits was another cultural ESs which referred to social relations among people in the neighbourhood. The indicator measures the Number of social gathering sites within the living area such as playgrounds, barbecue places, outdoor gyms and picnic sites (Varberg Kommun, 2023). Further, the number of each type of social site is not included since it is preferred to have one site which has a higher quality rather than several with a lower standard.

Educational sites was an appropriate indicator in the residential area in Göinge by and Göingegården The unit was the number of schools and educational areas because according to Peh et al. (2022) “Educational benefits arise from the provision of an environmental space where schoolchildren and preschoolers can visit to get inspired, be creative and learn about nature, as well as allowing them to connect to nature and build bonds for the future”. Educational sites can be meadows or forests since they have the potential to inspire, educate, and deepen our comprehension of the interconnectedness and importance of ecosystems to human life (Varberg Kommun, 2023). For all four indicators, the higher the final value the better in the scoring system in the table.

Temperature regulation from the category Local climate regulation , see Figure 4.1, was related to green space and trees. Forest cover in ESRS E4 describes the benefit from the number of trees in the area (EFRAG, 2023). Local temperatures were regulated by green areas and the number of trees located nearby (Brown et al., 2014). The more trees, the better the regulation of temperature. An incoming sun radiation (albedo) impact on urban microclimate and temperature was dependent on the tree coverage. In cases of a higher albedo on surfaces with low tree coverage the temperature increased in contrast to if the surface had tree cover and grass that was cooling. The temperature fluctuate with the amount of green space and trees (Smith et al., 2023). The unit for this indicator is °C since it measures the maximum temperature in the area. With this, it is possible to see how the temperature fluctuates with the amount of green space and trees. In the scoring system in the table, the lower the final value the better. There are available maps showing maximum temperatures combined with the height of the trees in an area during the time period 1st of June to 31 of August, and this is combined with the height of the trees see Figure 4.4 (MSB, 2023).

Figure 4.4: *The maximum temperatures in Varberg with description of the colouring. Illustration made with information from MSB (2023).*

The category Food security and economic impacts produced two indicators: Rate loss of potential crop yield and Agricultural land valuation, see Figure 4.1. The provisioning ESs food production was included in ESRS E4 (EFRAG, 2023). The **Rate loss of potential yield** describes the transition of agricultural land into residential areas and in combination with the market value of agricultural land is important to measure. According to Jordbruksverket (n.d.) the Swedish agricultural land will become more valuable with time and the possibility to produce food is more important than ever since the world's population is increasing while the area's agricultural land is decreasing. The unit for the rate loss of potential yield is tonnes/year, how many tonnes of agricultural yield that is lost per year. In the scoring system in the table, the lower the final value the better. There are statistics about the yield, in kilos/hectare, for Sweden's different municipalities which can be used to calculate it

(Jordbruksverket, nda).

The **Agricultural land valuation** can be used for valuation of the land used for construction buildings, to get a sense of the monetary value of the land (Jordbruksverket, ndb). The unit for this is SEK/hectare (Sweden). In the table's scoring system, the higher final value the better.

4.3.9 Step 8: Evaluation of potential indicators

In the evaluation of indicators for Göinge by and Göingegården, the assessment considers how well they aligned with Derome's goals, the measurement and understanding, the availability of data, and scientific support. Preference was given to indicators that were straightforward to measure, had clear data sources, and were scientifically validated. Indicators that were difficult to measure or lacked reliable data were not prioritised. In total of the 26 potential indicators it was 22 which are final indicators. For motivations on each of the indicators, see Appendix A.6. The end result from the evaluation of the indicators is found in Table 4.2.

Table 4.2: *Evaluation of the 26 potential indicators.*
(1) Is the indicator relevant to meet the needs of the user? (2) Is the indicator understandable? (3) Is the indicator usable in a sense that it is measurable and does it show meaningful results? (4) Is the indicator scientifically valid in a sense that the indicator is correlated to what it is designed to measure in a widely accepted manner?

Indicators	1	2	3	4
Species richness	✓	✓	X	✓
Pollination potential	✓	✓	X	✓
Biotope protection area	✓	✓	✓	✓
Red listed species	✓	✓	✓	✓
Threatened species	✓	✓	✓	✓
Invasive species	✓	✓	✓	✓
Protected Area Coverage	✓	✓	✓	✓
Soil sealing	✓	✓	✓	✓
Emissions	X	✓	✓	✓
Air Pollutants Absorption Rate	✓	✓	✓	✓
Land conversion rate	✓	✓	✓	✓
Water Contamination Level	✓	✓	X	✓
Infiltration trench	✓	✓	✓	✓
Retention basin	✓	✓	✓	✓
Runoff avoided	✓	✓	✓	✓
Rainfall intercepted	✓	✓	✓	✓
Green Space	✓	✓	✓	✓
Canopy cover	✓	✓	✓	✓
Green space factor	✓	✓	✓	✓
Green Space Accessibility	✓	✓	✓	✓
Active Transportation Accessibility	✓	✓	✓	✓
Community benefits	✓	✓	✓	X
Education	✓	✓	✓	X
Temperature regulation	✓	✓	✓	✓
Rate loss of potential crop yield	✓	✓	✓	✓
Agricultural Land Valuation	✓	✓	✓	✓

4.3.10 Final indicators with examples

The indicators which met all the criteria are 22 indicators, where Species richness, Pollination potential, Water contamination level and Green space did not make it. The example values provided in Figure 4.3, with all final indicators, are for Göinge by and the details of the calculations are found in Appendix A.7.

Table 4.3: *The 22 final indicators for Göinge by and Göingegården, with example values from Göingeby. Cultural ESs are in red, supporting ESs are in blue, provisioning ESs are in purple and regulating ESs are in yellow.*

Indicators	ESs	Unit	Initial	Maintained	Added	Removed	Final	Score	Comments
Biotope protection area	🔵	total no. of biotopes. (no. of each biotope)	7(3)						Related to ESRS E4
Red listed species	🔵	no. of species	15						ESRS E4
Threatened species	🔵	no. of species	2						ESRS E4
Invasive alien species	-	no. of species	-						ESRS E4
Protected area coverage	🔵	% (protected area/total area)	0,62%						ESRS E4
Soil sealing	-	% (paved area/total area)	-						ESRS E4
Emissions	-	CO2-eq.	-						Related to ESRS E4
Air pollutants absorption rate	🟡	kg/year	-						ESRS E4
Land conversion rate	-	hectar/year	-						ESRS E4
Infiltration trench	🟡	meter	-						ESRS E3
Retention basin	🟡	% (area of basin/drainage basin)	-						ESRS E3
Runoff avoided	🟡	L	-						ESRS E3
Rainfall intercepted	🟡	L	-						ESRS E3
Green space factor	🔵	%	-						ESRS E4
Canopy cover	🔵	%	21-30						ESRS E4
Green space accessibility	🔴	metre	-						Related to ESRS E4
Active transportation accessibility	🔴	km/cap	-						Related to ESRS E4
Community benefits	🔴	no.of different sites	-						Related to ESRS E4
Educational sites	🔴	no. of schools and educational sites	-						Related to ESRS E4
Temperature regulation	🟡	°C	32-34						Related to ESRS E4
Rate loss of potential crop yield	🟣	tonnes/year	317,04 (year 2023)						Related to ESRS E4
Agricultural land valuation	-	SEK/hectar	371,7 (year 2022)						Related to ESRS E4

5
Analysis

In this chapter, an analysis of the results are provided including what was surprising, what we, the authors, learnt and what was found difficult during the working process.

5.1 The DPSIR-E model

ESs and biodiversity include high levels of complexity and the DPSIR framework was found to be holistic and relevant. Since the combined framework for developing indicators was going to be used by Derome employees, it needed to be usable and suitable. It was surprising to find that neither usability nor suitability were included in the DPSIR framework despite its popularity within the field. It was therefore decided to include the additional evaluation steps and step 1 and 2 in the final combined framework to ensure both the usability of the framework and the suitability of the indicators.

5.1.1 International vs national

CSRD and the EU Taxonomy was created with the aim to increase the comparability between companies and their operations. There is the possibility that the aim of the reporting will suffer from differences between companies operating in different countries. One consequence could be different national standards or routines impacting the data collection and measuring. Further, companies with supply chains located in different countries may have problems when calculating the company's total impact with country specific data sets. Sector-specific standards would facilitate the data collection as well as ensure comparability and progress of environmental issues. This could also allow for translations of measurements for ESs and biodiversity.

Geographically specific standards adopted to different natural conditions across countries would further facilitate indicator data collection and measuring. ESRS E4 was constructed to be used all over the EU which has the potential to create challenges for example different geography in Europe. One example of this is desertification which is a relevant indicator as companies often operates in different countries but could be difficult to apply from a national context. The geography in in southern Europe is different than in the northern parts. In southern Europe desertification becomes a reality but not in the northern parts.

5.1.2 From value chain to site-specific

The translation and application of ESRS E4 to site-specific Swedish conditions was challenging due to their generality and perspective. Although the DPSIR-E framework had a holistic approach, some of the indicators in ESRS-E4 were too general in the sense that they were not applicable in Göinge by, Göinge gården or in Sweden. Although the Swedish standard, Nature Value Inventory (NVI) and the EU taxonomy used similar indicators, the EU taxonomy indicators were general and NVI indicators were site specific.

Translating the value chain perspective in ESRS E4 to site-specific nature values described the NVI was challenging and not straight forward. To reach the reporting requirements, ESRS E4 was used with some assumptions and adjustments in the creation of the site-specific indicators for Derome. These decisions were made based on the availability of data and representativeness in ESRS E4.

5.2 Developing suitable indicators

One of the most difficult moments of creating the indicators for Göinge by and Göingegården was ensuring their suitability. The process of finding indicators without considering what would be feasible was easy but finding the data was difficult for the complex ESs and biodiversity issue. If the indicators were used by field experts, the necessary measurements would have been easy. However, the continuous monitoring and measuring should be done by Derome which required another type of indicators.

5.2.1 Knowledge exchange

Since the framework was going to be used by non-experts, it was found that the knowledge exchange and communication between experts and the user of the framework was important. The main stakeholders in the process were the employees at Derome and the municipality ecologist and surprisingly there was no, or very limited, ongoing knowledge exchange between the parties. The municipal ecologist was skilled on how to collect data and how to increase ESs and biodiversity at different locations. Knowledge that was important to Derome and knowledge the company needed when reporting according to ESRS E4. Derome expressed a sense of locked in by the detailed development plan for their construction sites. Independently, the lack of knowledge exchange would affect their actions regarding biodiversity and ecosystems and the results in the sustainability reporting.

This lack of communication between the municipality and Derome was also surprising since they both aimed at improving ESs and biodiversity. In meetings with the municipality ecologist, it was perceived that the construction industry the lacked knowledge to take precautions of ESs for example what trees to be planted at the construction site. The ESs pollination would benefit by native trees such as oaks but instead beautiful trees with less contribution to the ESs such as magnolia were frequently prioritised. The choice would affects the pollination potential at the construction site.

5.2.2 Comprehensive or simple?

The DPSIR-E framework included an evaluation step to address the criteria adaptable to the knowledge and resources of the user. Throughout the indicator development process, the balance between accuracy and feasibility were considered. When selecting indicators, the balance of comprehensiveness and simplicity was important and difficult. Important in choosing the indicators was the indicators communicative power and how it was measured. A too complex indicator that needed comprehensive details would decrease the feasibility of the measure.

The choice with practical simpler measures and calculations comes with some loss of detailed information. For example, pollination potential, the indicator provided high level information on the operator's impact but lacked communicative power compared to the indicator green space factor. An indicator such as green space factor, which replaced pollination potential in the final set of indicators was easier to follow up and to communicate. Another example was biotope protection area which was chosen to represent biodiversity over species richness. Species richness required knowledge and effort in measuring or calculating the indicator.

5.2.3 Future applications

There will be a big need to develop indicators for ESs and biodiversity around Europe. Although ESs and biodiversity have been discussed previously in the scientific community, it has now transitioned to the commercial and to the public community where it has been considered a new topic. To develop indicators on national, regional or site-specific levels, DPSIR will continue to be useful. However, to achieve the usability and suitability necessary it might need alterations to better meet the contextualized demands and needs. To maintain the holistic perspective it is important to acknowledge and manage the complexity of ESs and biodiversity in general and in particular in the site-specific context. The DPSIR-E framework will contribute to increase the suitability of the created indicators which is important.

In this context, ESs and biodiversity were considered a new topic to some of the stakeholder. Involving stakeholders in developing the stakeholders were useful in addressing and bridging knowledge gaps such as the one between municipalities and construction companies. Involving stakeholders will facilitate knowledge exchange communication between experts and users when using a framework, the involvement of the municipal ecologist local proved to be very helpful.

The developed indicators needs to be tailored and tested for specific locations. To maintain the balance between comprehensive and simple indicators will be important to ensure feasibility without losing too many important details. The development of frameworks and indicators should be an iterative process and at times with stakeholder participation as it required continuous feedback and adjustment. Robust and usable sustainability framework and indicators will be best done and should be promoted as collaboration among different stakeholders, including companies, researchers, consultants, and regulatory bodies.

6 Discussion

One of the key messages of this master's thesis is the importance of reporting followed by the complexity that reporting on biodiversity and ESs entail. Further, how vital ESs and biodiversity and ESs are, and the importance of protecting and restoring them. The intention of this master's thesis is to demonstrate how the combined framework can be used to develop indicators for measuring ESs and biodiversity. Also, how the indicators can be customised for measuring and reporting according to a certain situation. Specifically, the framework constructed is used to generate indicators for reporting in accordance with ESRS E4 for Derome's operations regarding land-use.

6.1 Strengths & weaknesses

Evaluating the credibility of this master's thesis is important to ensure academic integrity, validity of the research and the impact it has and may have. With this, the credibility is discussed through the different components that make up this master's thesis: data, literature, methods, models, assumptions, estimations, limitations, sources of error and the case study.

6.1.1 Data & literature

One strength in this master's thesis is the usage of literature and data. Since the majority of the master's thesis is based on literature, it is important to evaluate the literature and the secondary data used. When using literature, the aim is to always go back to the original source to check the information used. When utilising sources from reputable organisations such as governmental bodies, supranational entities like the EU, and established organisations like IPBES, the credibility and trustworthiness of this master's thesis is increased. This is because these organisations are widely recognised for their expertise and neutrality. By drawing upon such sources, the thesis gains added credibility in its findings. One weakness in this master's thesis regarding literature is that the field of ESs and biodiversity is rapidly evolving which results in that some recent developments or findings may not have been fully incorporated into the thesis. However, as stated in the Method chapter when using articles as literature they have mostly been found via the database Scopus which only publishes peer-reviewed articles.

Regarding the combination of literature about the specific subject: ESs, biodiversity and ESRS E4 or CSRD there is not much literature to get support from due to the novelty of the subjects. Specifically, there are several articles and reports about using DPSIR to develop indicators about either biodiversity or ESs, but the method in them could never fully be used due to different scopes or geographical locations.

Regarding the interview study and the primary data obtained, there are some weaknesses related to the human factor. With two interviewers having separate interviews impacts the results, depending on how the questions are asked and also which follow-up questions are chosen. Further, depending on the interviewees and how they perceive the questions asked and the entire situation could affect their answers. Lastly, the interpretation of the primary data from the interviews could also contain bias from the authors which also has an effect on the results.

6.1.2 Method: interview & literature study

The chosen methods in the master's thesis can also be discussed. Firstly, the combination of a literature and interview study increases the validity however both of them have weaknesses that need to be addressed. Due to the scope of this master's thesis, literature regarding frameworks that can be combined to develop indicators, information on existing indicators for ESs and biodiversity, and suitable indicators for Göinge by and Göingegården are limited. This could be due to the specific scope of the master's thesis and the novelty of reporting on ESs and biodiversity according to CSRD. Regarding the interview study there is a limitation in the number of participants since there only were five interviewees. Since the generated data from the interviews should be as general for Derome as possible, this number could have been higher to get a better representation. However, the goal was also to interview people who have work tasks which include sustainability or sustainability reporting in some way which was a limiting factor when finding interviewees. Further, there were both representatives from the group but also one of the companies concerning construction sites which is a match for the aim of the interview study. It is important to not generalise the results from the interview study for the whole group of Derome or the construction and building sector.

6.1.3 Assumptions & estimations

For this master's thesis, ESRS E4 is used and interpreted by the authors. The Standards are quite extensive and non specific since the aim is to cover a large variety of industries within the EU. This led to assumptions being necessary. Further, due to the lack of published reports written according to ESRS E4 available, assumptions on what measures that the reports should entail is made. For example, impacts on biodiversity and ecosystems are mentioned in ESRS E4 and are therefore assumed to be of importance to report on. However, the term ESs is frequently used in this master's thesis since the term includes both the ecosystem and biodiversity. Since Derome does not have knowledge in biology and ecology within their company, this had to be taken into consideration when developing the indicators for measuring ESs and biodiversity. This resulted in simplified measurements being favoured over more complex and thereby more precise measurements.

6.1.4 Limitations & sources of error

The scope of this master's thesis resulted in the limitation that the results of the developed indicators are site specific to Göinge by and Göingegården. However, the combined framework is general and can therefore be used for other purposes that includes another scope or issue. However, the framework is intended to be used on environmental issues induced by human activities. Some sources of error occurred throughout the thesis. Firstly, errors might have occurred in the interpretation of both ESRS E4 but also legal documents provided by the Swedish Government since the authors lack knowledge and experience in that area. Secondly, since the indicators are based on the DPSIR-E framework there is a risk that some indicators are left out if the responding pressure, state change or impact is not considered in the framework. Another limitation that caused some discrepancy with ESRS E4 was the scope of this master's thesis. While the reporting directive includes the whole value chain and the effects that the company's activities have on biodiversity and ESs, the created indicators only apply to the construction stage, more specifically the use and conversion of land. Therefore, the resulting indicators from RQ 3 can only be applied to the construction stage of Derome's operations in Göinge by and Göingegården. CSRD requires reporting over the full value chain which requires even more indicators being developed. Since Derome uses a lot of wood in their constructions, it is likely that the forestry producing the raw material has a large impact on biodiversity and ESs which therefore needs to be investigated further. However, the combined framework DPSIR-E can be customised for every site of Derome's regarding developing indicators for ESs and biodiversity but it has to be done individually for each site.

6.2 Contributions

This master's thesis contributes to increased knowledge regarding reporting according to ESRS E4 and the results shows new knowledge contributing to the research field. Since the thesis is made in cooperation with Derome, the results are aimed at tailoring the combined framework to suit their needs. However, the framework can be used by other actors in the construction and building sector, and can therefore be seen as contributing to increased knowledge regarding reporting according to ESRS E4. Furthermore, the combined framework DPSIR-E and the resulting indicators for Göinge by and Göingegården contribute to increased knowledge in the field because they are examples on how to deal with the issue of measuring on ESs and biodiversity, and not only on ESRS E4. This includes indicators which concern cultural ESs which are important in residential areas. The mapping of current Swedish legislation and upcoming reporting demands (ESRS E4) regarding ESs and biodiversity from the EU resulted in a comprehensive overview. During the initial parts of the thesis, the master's thesis written by Andréasson (2023) was used, which focuses on how businesses operate with and understand biodiversity. Further, the study by Moss et al. (2021) was used since it included an implementation of the DPSIR framework. This master's thesis provides a more specific analysis focusing on ESRS E4 and only one company, Derome, in contrast to the thesis written by Andréasson

(2023). Further, the framework presented in this master's thesis has been modified from the one presented in Moss et al. (2021) to include three additional steps to suit the aim of the thesis.

6.3 Future research

The limitations of this master's thesis opens up for future research within this field. The most important aspect for future research is a standardised method for measuring and reporting ESs and biodiversity, according to ESRS E4. As previously mentioned, sector specific indicators or instructions need to be provided in order to properly measure the impact of different operations. Further validation of the final indicators for Göinge by and Göingegården and construction sites in general could be done for future research, likewise with the usage of DPSIR-E to develop indicators for a different operation. Long-term monitoring of the effect of tracking and measuring these indicators could provide valuable insights into the effectiveness of conservation and restoration efforts.

7
Conclusions

The aim of the master's thesis was to investigate how ESs and biodiversity can be measured and how use the results to further report it aligned with CSRD, specifically ESRS E4. The findings in the results shows that for Derome's operations, the indicators derived from the combined DPSIR-E framework can be used for measuring of ESs and biodiversity. Further, the measurements can be used for reporting according to CSRD, more specifically ESRS E4. In general, the findings also highlights the importance of the right indicator for the situation, and the choosing of them requires comprehensive knowledge of the area and of ESs and biodiversity where the measurements take place. They have to be suitable in order to fulfill their aim, and suitability of them varies since the aim of the indicators and measurements also varies. Regarding the RQs, the following were concluded about the results, in the same order:

1. The application of ESRS E4, on Derome's operations regarding land-use, is measuring ESs and biodiversity with indicators, to further align these with Derome's business plans and operations to restore and protect biodiversity and ecosystems.
2. The usage of the combined framework DPSIR-E, which has DPSIR as a foundation with additional steps, can be used to identify suitable indicators for ESs and biodiversity to different operations and situations.
   (a) To ensure suitability of the indicators, the word suitable defined according to the four sub-questions to RQ 2, were all incorporated into the combined framework DPSIR-E as individual steps. This was incorporated into step 1,2 and 8 in the DPSIR-E framework.
3. In total 22 suitable indicators were identified for Göinge by and Göingegården, see Table 4.3.

Other conclusions found, related to the analysis or the results, were:

- The need for more detailed sector specific disclosure requirements are needed to ensure comparability within the sector.
- There is a need for common monitoring data points (indicators) for nations and sectors.
- There are difficulties in the translation from CSRD's value chain perspective into a site-specific level when monitoring, compiling data and reporting.
- To some extent, prior knowledge about ESs and biodiversity is a prerequisite for using the combined framework in order to identify relevant and suitable indicators for the situation.
- There is a contradiction between the complexity of ESRS E4 and companies' current understanding of ESs and biodiversity. Hence in this master's thesis the balancing act between comprehensive and simple was difficult.

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A
Appendix

A.1 Search words

Table A.1: *Search words used in Scopus and Google Scholar for collection of secondary data.*

Search words		
Air quality	Agriculture	Alpha-beta-gamma diversity
Alteration	Analysis	Assessment
Biodiversity	Climate change	Change
Construction site	Construction stage	Crop production
Cultural ecosystem services	CSRD	Decline
Deforestation	Demand for housing	DPSIR
Ecological	Ecosystem mapping	Ecosystem service
Emissions	Ecological	ES cascade
ESRS	ESRS E4	Eutrophication
Evaluation	Exploitation	Food security
Framework	Genetic biodiversity	GHG
Global	Global warming	Green corridors
Habitat	Habitat fragmentation	Habitat modification
Human health	Human well-being	Increase
Indicators	Indirect drivers	Invasive species
Invasive alien species	Land conversion	Land cover
Land degradation	Land transformation	Land-use
Land-use change	Leaching	Measurable
Method	Millennium Ecosystem Assessment	Nature
Native species	NCP	Nutrient cycling
Phenotypic	Photosynthesis potential	PICABUE
Planetary boundaries	Plantation	Pollution
Pollination	Pollinators	Population growth
Provisioning	Purification	Regulating
Runoff	Semi-constructed interviews	Societal
Society	Soil	Soil biodiversity
Soil formation	Soil properties	Soil sealing
Species diversity	Species evenness	Species richness
Supporting	Sustainable	Sustainability reporting
Thematic analysis	Threatened species	Urban ecology
Urban expansion	Urbanisation	Vegetation cover
Water	Water pollution	Water regulation
Water run-off	Yield	

A.2 Interview manuscript

There are in total 13 interview questions in the interview manuscript, excluding follow-up questions. They are categorised according to the three RQs, with an exception for the introduction questions. These are present to provide more primary data of the company's own values. Further, the interview questions are all related to the RQs to provide further primary data to the master's thesis which can not be achieved through literature study.

Introduction

- What does ecosystem services and biodiversity mean to you?
- How would you say ecosystem services and biodiversity are important to Derome?

Reporting requirements for Biodiversity and ESs

- Have there been any challenges that you at Derome have encountered regarding meeting these legal requirements for reporting biodiversity and ecosystem services?
  - How are these challenges addressed?
- How does Derome collaborate with relevant authorities or organisations to ensure that their reporting on biodiversity and ecosystem services aligns with legal requirements?
- Are there any specific demands or expectations from stakeholders or society at large regarding Derome's reporting on biodiversity and ecosystem services, beyond legal requirements?
  - How do you address these expectations?

Suitable Indicators for measuring Biodiversity and ESs

- Do you and if so, how do you involve various stakeholders at Derome when it comes to biodiversity and ecosystem services in the company's operations?
- How do you think a framework with indicators could assist you in your work with biodiversity and ecosystem services?
- Do you see any difficulties and/or opportunities in using a framework to develop indicators for biodiversity and ecosystem services for internal use within the company?

How to identify indicators for Biodiversity and ESs

- Which actors, both external and internal, do you believe would benefit from the results of the indicators?
- How would you use the results on biodiversity and ecosystem services within the company, do you think?
- If so, how do you currently work with indicators on ecosystem services and biodiversity?
  - If not, how do you currently work with ecosystem services and biodiversity?

- Why does Derome want to collect data regarding biodiversity and ecosystem services for its activities?
- Are there any current sources of data/information on biodiversity and ecosystem services that you currently utilise?

A.3 The Swedish Environmental Code

Chapter	**Paragraph and explanation**
1	**1§:** The Swedish Environmental Code is meant to be applied to ensure that damages on humans, the environment, biodiversity, natural- and cultural environment, aquatic ecosystems are minimised (SFS 1998:808).
2	**2-3§§:** Precaution in terms of possible negative impacts on human health and the environment should be taken into consideration when conducting any form of activity **5§:** The use of material and harmful substances are to be used in a manner that minimises the amount of waste and energy needed for the project. **6§:** The choice of area in terms of water and land should be made in order to meet the purpose for the project whilst considering where the smallest impact of the project might have on human health and the environment. **8§:** The approval for initiating any form of activity shall not be in conflict with the detailed development plan created by the municipality. If however any form of damage occurs from a project, the part conducting the project is responsible. If the damage is irreversible, the part responsible shall compensate for this. **9§:** Projects that might result in damages must only be conducted if the reason behind the project is considered to be beneficial for the society. What is considered to be of societal benefit is decided upon by the Swedish government. **10§:** It is stated that water and land areas should be used for the most suitable good for societal economising purposes (SFS 1998:808)

3	**1-5,7§§:** Agricultural practices for economising purposes, forestry and areas containing materials useful for society are considered to be of national interest and are therefore being favoured over construction of residential buildings. **3§:** Certain areas that are considered to be sensitive for change are to be protected and hence avoid being used for activities. **6§:** Areas with cultural and natural values are to be protected to ensure outdoor life for people. Green areas in proximity or within urban areas are of essence to ensure recreational values for people in that area. **12§:** It is the county administrator's responsibility to collect the result from investigations and mapping the areas within their county. This information should be made available for the municipality, governmental agencies or other potential actors that are required to conduct an Environmental Impact Assessment (EIA) (SFS 1998:808).
4	**1§:** Exploitation of land area are only permitted if it is not in conflict with 2-8§§ (which lists multiple areas of special interest by name) or if it does not damage the natural and cultural values in that area in a tangible manner. **2§:** Areas that might be of relevance within the geographical scope of this master's thesis are the shoreline in Halland and Kullaberg and Hallandsåsen with the shoreline in its proximity (SFS 1998:808).
5	**1§:** The Swedish government has the authority to enforce Environmental Quality Standards (EQS) in areas with the aim to ensure a stable protection of that area in favour of the environment and human health. The responsibility for ensuring that activities are inline with the EQS is delegated to the municipalities and governmental agencies. **4§:** Activities are not to be permitted by the municipality or governmental agencies if the water quality might be disturbed by that activity. **5§:** Permission for activities that might lead to effects which expose a risk for exceeding the EQS only can be approved if an action plan and agreements on compensation are constructed. Permission can be granted if positive effects on a longer time period and of a larger area are considered to be of greater value than possible negative effects short term and on a smaller area (SFS 1998:808).

6	**1§:** Entails regulation regarding assessment of possible effects in the environment, both for planning the state of a project and possible measures needed to be taken. **2§:** Both direct or indirect effects of which are negative or positive, temporary or consisting, cumulative or non-cumulative and impacts on different temporal scales are included. **3§:** Governmental authorities or a municipality that constructs or makes adjustments in the plan are obligated to create a Strategic Environmental Assessment (SEA) if the adjustments might result in effects on the environment in a substantial manner. **9§:** The SEA should be done in consultation regarding the scope of the assessment, include an Environmental Impact Statement (EIS) and create space for opinions that might arise during the process. The EIS and the opinions should be incorporated into the plan or program. In cases where it is suitable the results from the SEA can be used for regulatory purposes. **11§:** The EIS should summarise the purpose and content of the plan or program and how it is related to other programmes and plans of relevance. The state of the environment and how it might be affected if the plan or program is not implemented, if the area is likely to be affected substantially, current environmental issues of the area, its relation to EQS, possible effects on the environment and how these can be mitigated. Finally, considerations that have been taken into account should be included in the EIS. **13§:** The extent of the EIS should be adapted to fit the methods used, current legislation and the degree of detail according to the plan or program. **15§:** The municipality or the governmental agency should create the EIS at an early stage of the plan or program and make this available for the parties of interest and ensure that opinions regarding the EIS can be uttered. **16§:** It should be stated how the decision on accepting a plan or program including a SEA has been made by including how environmental aspects has been incorporated, consideration regarding the EIS and opinions, reasoning for accepting the specific plan or program and lastly what measures are made to monitor the environmental impact. **19§:** The municipality or the governmental agency responsible are obligated to get knowledge regarding the possible substantial impact on the environment that the plan or program might entail. **20§:** If needed, a specific environmental assessment (EA) can be conducted. **23§:** If the planned project might result in significant effects in the environment, the impacts regarding the project must be examined further to investigate if permission should be granted for continuing with the project.

	24§: The investigation should be done in consultation between the county administration, a supervisory authority and other actors that may be affected by the environmental impact from the project. **26-27§§:** It is later the county administration that are responsible for deciding if the project might result in significant effects on the environment which this can not be overruled in particular. **42-44§§:** Permission for continuing the project should be done based on the results from the EIS conducted in the specific EA and should be made available for the parties involved as soon as possible after the decision has been made (SFS 1998:808).
7	**1-14§§:** Right of public access, regulations on national parks, nature reserves, areas of cultural reserves, natural monuments, protection of biotopes and shoreline protection etc., are explained. **7-8,11-12,17§§:** Areas that are classified as this are not to be exploited but should be protected. However, small activities might be permitted in nature reserves, biotope protected areas or shoreline protected areas if it is viewed as important for society. The decision is made by the county administration, governmental agency or the municipality that developed the protection. **18§:** Further, projects might be permitted in shoreline protected areas if it is considered to be of benefit for development of the countryside. **19-22§§:** Areas that are protected for environmental purposes and for their water resources are protected by chapter seven 21-22§§ (SFS 1998:808).
8	**3§:** the importance and obligations for actors to prevent introduction and mitigation of invasive species (SFS 1998:808).

Table A.2: *An overview of the parts of the Swedish Environment Code related to biodiversity, ecosystems and Derome.*

A.4 Relative pollination potential

Measuring RPP is a complex process since it depends on multiple factors. A more detailed description of the calculations can be found in (Zulian et al., 2013).

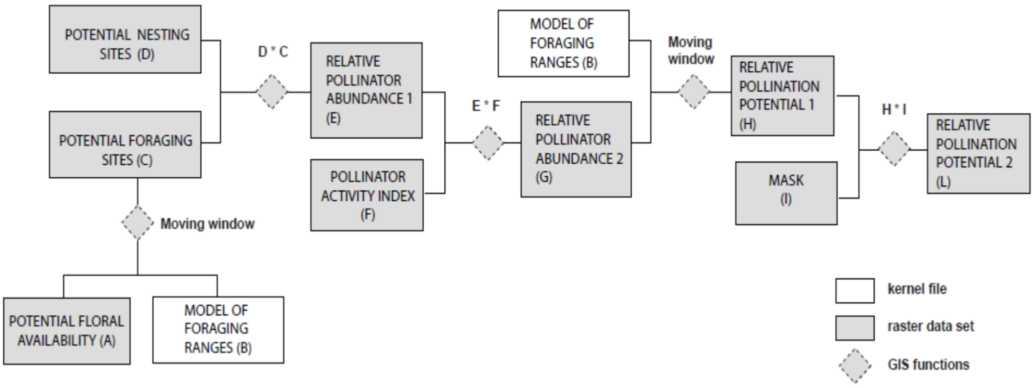

__Figure A.1:__ Relative pollination potential (Zulian et al., 2013). CC-BY-4.0

A.5 Air Pollutants Absorption Rate

In order to calculate the indicator called **Air Pollutants Absorption Rate**, in the unit kg/year, calculations have to be made. The calculations include counting the trees in a specific area, identifying the most common species and using a tool called i-Tree Eco online. The calculations have a limitation, which is that the area for the calculation has to be in Sweden due to data limitation.

Step 1:
Firstly, the tree cover percentage over the specific area must be determined. It can be determined with the help of Boverket's website and GIS-tool (MSB, 2023). Use the map, determine the specific area and read the percentage of tree cover in the area.

Step 2:
Once the percentage of trees are determined in the area, the area consisting of trees must be determined to get an estimation of the total no. of trees in the specific area.

$$\text{Tot. area } (\text{m}^2) \cdot \text{Tree coverage } (\%) = \text{Area with trees } (\text{m}^2)$$

To estimate the total number of trees in the area, a smaller section of area will help estimate this. By taking a square of land area, count the number of trees there and then use the results from the last calculation, an estimation of the total number of trees can be made.

$$\text{Area with trees } (\text{m}^2) \cdot \text{No. of trees in a specific area} \left(\frac{\text{trees}}{m^2}\right) = \text{Tot. number of trees}$$

Step 3:
As previously mentioned, the most common species of trees must be determined. The reason behind is that the online tool i-Tree Eco needs specific species and the no. of trees to determine the Air Pollutants Absorption Rate.

Step 4:
Insert all gathered data into the i-Tree Eco online tool and read the results (I-Tree Eco, ndb). Note that the results are per 20 years, so divide the numbers with 20 to get it annually.

A.6 Step 8: Evaluation of indicators for Göingeby

A.6.1 Species richness

Species richness meets three out of the four evaluation criteria. The use of this measurement is to some extent relevant for Derome since it will provide both the company and other stakeholders with information regarding impacts on species that their operation has. To ensure that the second evaluation criteria would be met, a reference value would be needed for the audience to assess if the result of the indicator is high or low. Further, there are a few more downsides with this measure. Species richness is a time consuming and resource demanding process which requires biological knowledge, which none of the employees at Derome has. Therefore, using species richness as an indicator for biodiversity for Derome is not favourable since it fails to meet the third evaluation criteria. However, species richness is a widely used measure which leads to the last criteria being met (Roswell et al., 2021).

A.6.2 Pollination potential

Pollination potential passed three out of four of the criteria in the evaluation step. Pollination and pollinators are of importance and hence mentioned several times in ESRS E4 because of this (EFRAG, 2023). Because of its strong connection to ESRS E4 it is a relevant indicator for the user. Moreover, the indicator is considered understandable since it is a percentage and the higher the better. On the third criteria it did not pass, due to lack of data and measurability. It is a complicated process to measure this and therefore it is not suitable for Derome to measure this at Göingeby (Zulian et al., 2013). However, it does show meaningful results and is scientifically valid because it is the EU which created the index.

A.6.3 Biotope protection areas

Biotope protection areas are measured in both no. of different biotope protection areas and no. of each biotope. Using the two metrics enables Derome to report according to ESRS E4 since the effects that their operations have on protected areas shall be disclosed but also that it is an important site for biodiversity (EFRAG, 2023). Further, the two metrics are designed to be complementary with the aim of generating both information on quantity and quality of the biotope protected areas that are assessed. The second criteria is considered to be met since the results of the metrics are easy to understand. However, there might be some difficulties in understanding what is considered as better when comparing the composition of different biotope protection areas. Are five willow banks in one area more worth than one line of tree and one stone fence in another? Moreover, the two metrics are considered to be usable since information on this should be included in the NVI conducted prior to construction and building. These metrics also display trends since monitoring can be facilitated throughout the construction process, which leads to the third criteria being met. Lastly, the indicators are considered to be scientifically valid since the classification system is constructed by governmental bodies and are widely used within the construction industry and society. Given this reasoning, both of the metrics and therefore the indicator is considered to have passed the evaluation criteria.

A.6.4 Red listed species

The indicator **Red listed species** fulfils the first evaluation criteria since effects on red listed species are required to be included according to ESRS E4 (EFRAG, 2023). The red list is understandable since it provides clear metrics regarding species and their current state in the area. Further, data regarding red listed species are accessible both in the NVI conducted prior to the construction and in the Swedish version of the red list (SLU Artdatabanken, 2020). New assessments after the project is done can also be made to show meaningful trends. Since the red list is provided by IUCN, which is one of the leading organisations regarding the environment, the source is to be considered scientific valid (IUCN, nd).

A.6.5 Threatened species

Threatened species is a categorisation that is included in the red list. It is included since it is specifically mentioned in ESRS E4 which results in meeting the users need (EFRAG, 2023). It is considered to be understandable since the terminology is widely spread. Further, data regarding threatened species is accessible both through the NVI and the Swedish version of the red list (SLU Artdatabanken, 2020). This leads to the indicator being measurable and possible trends can be identified through continuous observation and measurements in the area.

A.6.6 Protected area coverage

Protected area coverage contains multiple types of protected area (Länsstyrelsen, nd) and this indicator meets Derome's need since it is included as a requirement according to ESRS E4 (EFRAG, 2023). What is a protected area is considered to be of common knowledge leading to the second evaluation criteria being met. Further, the indicator is measured in ha or percentage which both leads to the third criteria regarding possibility to measure and show trends being met. Lastly, measuring the percentage of protected areas is used in the EU Biodiversity Strategy for 2030 which leads to the indicator being scientifically accepted (EC, Directorate-General for Environment, 2021).

A.6.7 Soil sealing

Soil sealing is mentioned in ESRS E4 which results in the indicator being important to enable Derome to fulfil the need for reporting according to ESRS E4 (EFRAG, 2023). To ensure that the second criteria, regarding understandable indicators is met, soil sealing needs to be explained in short yet properly. The indicator is measurable since data such as maps from the project plan and Google Earth can be used (Peh et al., 2022). This leads to the third evaluation criteria being met. Lastly, soil sealing is considered a widely used indicator for measuring environmental impacts, which results in the fourth evaluation criteria being met (Tobias et al., 2018; Peh et al., 2022).

A.6.8 Emissions

Emissions meets three of the four evaluation criteria. The reason for it not meeting the first criteria is that it is not a specific part of ESRS E4. However, it is mentioned in ESRS E2 which entails reporting standards on pollution which in turn should be referred to in ESRS E4 (EFRAG, 2023). Data regarding the fuel use is to be found within Derome which together with emission factor can be used to calculate the emissions from the construction site (Derome, 2023a; Peh et al., 2022). Measuring and reporting on emissions are widely accepted as well as the connection it has to biodiversity (Peh et al., 2022).

A.6.9 Air pollutants absorption rate

The indicator **Air pollutants absorption rate** meets all four of the evaluation criteria. It meets the needs of the user since pollution regulation can be seen as regulating ESs which is a part of ESRS E4 (EFRAG, 2023). There might be some difficulties in understanding the relationship between pollution mitigation and trees. This can however be reduced by providing a proper description to the reader when used as an indicator. The indicator is measurable when using the i-Tree Eco tool (I-Tree Eco, ndb). Further the results can be used to illustrate possible changes in air pollutant mitigation. Lastly, the correlation between air pollution mitigation and occurrence of trees are and the measurements are widely accepted and scientifically proven (Grote et al., 2016).

A.6.10 Land conversion rate

Land conversion rate meets all four of the evaluation criteria. Since land-use change is mentioned in ESRS E4, the rate of land conversion is considered to meet the need of the user (EFRAG, 2023). The indicator is considered to be understandable for the intended audience due to the simplicity of the unit and the aim of the indicator. Further, the indicator is measurable since data can be found in maps that can be covered in the detailed development plan for Södra Trönninge which includes Göinge by and Göingegården. Data from Google Earth can also be used to measure land conversion rate (Peh et al., 2022). Lastly, land conversion rate is a widely accepted and scientific measure leading to the fourth criteria being met (Peh et al., 2022).

A.6.11 Water contamination level

Water contamination level did not meet all criteria. The indicator is related to flooding due to soil sealing, and a proposed unit to measure the polluted water is concentration in mg of pollutants/L of water. However, it did not pass the criteria for evaluation step since lack of data and not being measurable at the current time.

In addition, this indicator is limited to what it can show as results and what it could contribute to.

A.6.12 Infiltration trench & Retention basin

Infiltration trench and **Retention basin** both passed all four evaluation criteria. Water is an important issue, including in ESRS E4 (EFRAG, 2023). More specifically, the regulating ES water regulation is of importance to the nearby surroundings. They are relevant indicators for Derome since they are connected to both Göingeby and ESRS E4, since these are also compensation measures which need to be reported. It is both understandable and provides meaningful results because the unit for Infiltration trench is a ratio and percentage and the unit for Retention basin is in metres, both comprehensible. They are measurable because they require some type of map over the area to measure. In both cases it is the County Administrative Board who provided the background information and the unit for the indicator and therefore considered scientifically valid.

A.6.13 Runoff avoided & Rainfall intercepted

Both **Runoff avoided** and **Rainfall intercepted** met all of the evaluation criteria in step 8. Same as for the indicators Infiltration trench and Retention basin, the regulation ESs water regulation is of importance for the surroundings but also the report according to ESRS E4 about compensation measures. This is also why these two indicators are considered relevant to meet the user's needs. They are both understandable and provide meaningful results because their unit is easily interpreted because it is in litres, which is an estimation of the amount of runoff avoided and rainfall intercepted based on the number of trees (I-Tree Eco, ndb). The fourth criteria is if the indicators are scientifically valid, and since the tool used to calculate it is proven and in addition the municipality of Varberg uses the same it is valid.

A.6.14 Canopy cover

The next indicator which passed all of the four criteria is **Canopy cover**. It fulfils the user's requirements as it aligns with Sweden's guiding principles regarding green space coverage, aiming for a 30% canopy cover (Region Skåne, 2023). Further, it is related to ESRS E4 since trees are providing regulation ESs, and are important to biodiversity and species located in the area (EFRAG, 2023). It is also an indicator which is understandable since it can be put into the context of well-being and aesthetics of the area. There is data available at the Swedish National Board of Housing, Building and Planning (Boverket) which includes maps with information on canopy cover. This results in the third criteria being met. Lastly, it is scientifically valid because it is used in the context of urban areas in Sweden (Region Skåne, 2023).

A.6.15 Green space

The indicator **Green space** succeeded in meeting all of the four evaluation criteria. Since green spaces can be connected to multiple ESs, for example cultural ESs (Chang et al., 2017), the indicator fulfils the need of the user. The indicator is considered to be understandable since it is measured in percentage of a total area which is assumed to be of common knowledge. Further, the indicator is measurable since data can be found on Google Earth or maps provided by the municipality (Peh et al., 2022). The results are considered meaningful as they illustrate the state of the area. Lastly, even though the indicator passes all criteria it is not indicating the quality of Göingeby and since two indicators were suggested for the same goal, to measure the amount of green space. Because the indicator Green space factor indicates more the quality of the green areas, the Green space indicator is discarded.

A.6.16 Green space factor

Green space factor is another way to measure the amount of green space in the area, and it met all of the criteria. It meets the needs of the user in the sense that it is related to the guiding values in Sweden about the cover of green areas, or canopy cover, should be 30% (Region Skåne, 2023). With this, Derome is able to meet the demands and use this in marketing and for the residents' well-being. Furthermore, it is understandable because it shows a percentage of eco-efficient areas in the total area. It is meaningful in the sense that it is not only measuring the amount of green space but the quality of it as well. Since it is commonly used in detailed development plans and by Boverket it is considered scientifically valid. This indicator is more nuanced and shows more of the quality of the green space in the area, in comparison to the indicator named Green space.

A.6.17 Green space accessibility

Next, **Green space accessibility** met every criteria in the evaluation step. This is considered a cultural ESs and meets the needs of the user in the sense that it will provide recreational value to Derome's residents at Göingeby. Further, it is understandable and provides meaningful results since it is an established measurement used in Sweden: to maximum have 300 metres to nearest green space (Region Skåne, 2023). It is measurable since there are data tools available like Google Earth or similar (Peh et al., 2022). Lastly, it is considered scientifically valid because of it being a guideline value for urban green spaces in Sweden (Region Skåne, 2023).

A.6.18 Active transportation accessibility

Further, **Active transportation accessibility** is an indicator which passed all four criteria. It is included because it is a cultural ESs in the area of recreation and hence of importance (Brown et al., 2014). It is both understandable and shows meaningful results because the unit is km of pathway per capita, hence an estimation of how much pathway for active transportation that is available for each person living in the area. It is measurable since there is data available to measure and lastly since this particular indicator is mentioned in Brown et al. (2014), which is in collaboration with different research institutes, it is considered scientifically valid.

A.6.19 Community benefits

Community benefits is another indicator which met three out of four criteria. By tracking the different social gathering sites in the residential area, Derome can see how much potential there is in the area for community benefits and socialising. This can be connected to Derome's marketing as well. It is understandable and it shows meaningful results since the number of different sites shows the potential for different social gatherings. However, it is not scientifically valid because no valid literature could support this specific indicator. But it is included anyways because through the interview study and personal communication it showed how important it is for both the residents in the area but also Derome.

A.6.20 Educational sites

The **Educational sites** indicator passed three out of the four criteria. It meets the need of the user in the sense that Derome might benefit from tracking educational areas, both for the residents but also Derome's marketing which is mentioned in the interview study. It is understandable because the unit is straightforward with the number of educational sites where children can learn and be inspired (Varberg Kommun, 2023). Further, it is measurable since Derome has access to maps of the area and it shows meaningful results since if this was lacking it is important to improve this area. However, the indicator did not meet the criteria of scientifically validity because it is not an established indicator or unit to use. Although, since the municipality of Varberg uses this and because Göingeby is located in Varberg the decision to include this indicator was made.

A.6.21 Temperature regulation

Temperature regulation is the next indicator evaluated and it passed every criteria. It meets the needs of the user since with this Derome is able to track internally how their operation affects the local climate regulation in relation to green spaces, trees and albedo. Since the indicator is connected to different surfaces in the area, and it measures the maximum temperature in the specific location it is both understandable and shows meaningful results. Further, since the results are shown in a map it is easier to interpret because it is visual (MSB, 2023). It is considered scientifically valid because the data and the map is provided by Boverket in combination with tree cover.

A.6.22 Rate loss of potential crop yield

The indicator **Rate loss of potential crop yield** successfully met all four evaluation criteria. The user in this case is mostly Derome since Göingeby and Göingegården are built on agricultural land, which means that there is a loss of potential crop yield which is important to consider during decision making. Further, it is understandable and shows meaningful results since it is a quantity of potential crops lost each year to get an estimation. The data is provided by Jordbruksverket which is a governmental organisation in Sweden, hence it is scientifically valid. Further, food and agricultural crop yield is of national interest (SFS 1998:808 3 ch. 4 §). However, the land can be used for reasons that are classified as significant public interests of which housing is classified (Länsstyrelsen Hallands Län, 2022).

A.6.23 Agricultural land valuation

Lastly, the indicator **Agricultural land valuation** passed all four evaluation criteria. It meets the needs of the user since it is important to be transparent with where Derome's operations take place and what it entails. The land valuation shows how important food production is, which is mentioned in ESRS E4 as sustainable land (EFRAG, 2023). Further, it is understandable and shows meaningful results since it is a monetary value of land, which over time will show how important it is in society. It is measurable since data is easily accessible for Derome to use. The data is provided by Jordbruksverket, hence it is scientifically valid.

A.7 Calculation of indicators at Göinge by

Eight indicators are calculated for Göingeby and the results can be seen in Figure 4.3. This is to illustrate how the indicators are calculated.

A.7.1 Biotope protection area

The total number of and the number of different biotope protected areas is found in the NVI over Södra Trönninge (Sörensen, 2015).

A.7.2 Red listed species

The number of red listed species is found in the NVI over Södra Trönninge (Sörensen, 2015).

A.7.3 Threatened species

The number of thretened species is found in the NVI over Södra Trönninge (Sörensen, 2015).

A.7.4 Protected area coverage

According to Länsstyrelsen (n.d.), there are no types of protected areas at Göinge by (Länsstyrelsen, nd). However, in the NVI a total of seven biotope protected areas are included. The results from the map in the NVI over Göinge by, see Figure 2.8, was used and drawn in the map tool at the webpage "eniro.se" (Eniro, 2024). The width of the biotope protected lines were assumed to be 1 m. With this, the area of the biotope protected lines is calculated. The area of the other biotope protected areas were added to this resulting in a total sum. This sum was then divided with the total area of Göinge by, resulting in a ratio.

Area of biotope protected areas (lines): $(2040 + 297,7 + 586,1 + 91,6 + 718,8 + 529,9 + 220,7 + 190,3)m \times (1)m = (4675,1)m^2$
Other biotope protected areas: 2823m^2
Total area of Göinge by = $(120)ha \times ((10000m^2) \div (1ha)) = 1200000m^2$
Percentage of biotope protected areas: $((4675,1 + 2823)m^2 \div (120000)m^2) \times 100 = 0,62\%$

A.7.5 Canopy cover

Data on canopy cover can be found at Boverket's map (Boverket, 2023c). By searching for Göinge by reading the legend the value of canopy cover can be determined. In this case, the entire region of Södra Trönninge has a canopy cover of 21-30 %.

A.7.6 Temperature regulation

To calculate this, Boverket's GIS-maps are used (MSB, 2023). The area of Göinge by is found by searching for the area, to further look for the darkest colour and then reading the legend for an interval. In this case, by 2022, the maximum temperature at Göinge by was 32-34 °C.

A.7.7 Rate loss of potential crop yield

From Jordbrukverket, the crop yield in kg per hectare for the year 2023, for the fall and spring, is shown for Sweden's different regions (Jordbruksverket, nda). The region of Halland is chosen, and the crop yield for fall and spring is added together and further multiplied with the total area of Göinge by. Since Göinge by consists of only agricultural land, the entire area of 120 hectare is used 2.8. The calculation is for the year 2023:

$$(1,321 + 1,321)\frac{tonnes}{hectar} \times (120) hectar = 317,04 tonnes$$

A.7.8 Agricultural land valuation

For this indicator statistics database from Jordbruksverket is used (Jordbruksverket, ndb). In the database the following are filled in:

- price per hectare, tkr per hectare
- Götalands södra slättbygder
- 1-10 hectare of agricultural land
- year 2022 (Jordbruksverket, ndb).

With this, the statistics show the value of 371,7 TSEK/hectare for 2022.

A.7.9 Other indicators

The rest of the indicators are not calculated due to two reasons. One, they are not relevant until residential buildings are done and second they require on-site measurements which could not be done, and all of these are marked with "-" in the table.

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