BIODIVERSITY FOOTPRINT ASSESSMENT OF VTT

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Authors: Jaakko Pöyhönen, Eetu Räisänen
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Supervisors: Stefan Baumeister, Sami El Geneidy

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

ABSTRACT

Author
Jaakko Pöyhönen & Eetu Räisänen

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Abstract

Biodiversity loss is one of the greatest environmental threats. The importance of biodiversity for people, societies and businesses cannot be overstated. It is therefore important to be able to assess the human-caused biodiversity impacts and how to mitigate them. Based on the direct drivers of biodiversity loss, it is possible to assess the biodiversity footprint of different organizations. In our work, we assess VTT's biodiversity footprint using the method developed by researchers at the University of Jyväskylä. Our aim is to assess the total biodiversity footprint of VTT, the most material activities causing it, how to reduce the biodiversity footprint and what other organizational improvements could be done. We will also look into what extent the methodology developed by researchers of University of Jyväskylä can be applied to the Science Based Targets for Nature framework.

VTT's total biodiversity footprint in 2022 was 105,73 nBDe, most of which was generated by district heating, business services, machinery and equipment. Potential targets for reducing the biodiversity footprint include reducing the share of bio-based fuels for energy, avoiding or minimizing the share of biodiversity intensive activities and seeking to reduce the volume of harmful activities. Organizational improvements are related to financial and environmental accounting, which could help to build a more efficient system for assessing the biodiversity footprint in the future. Regarding the comparison of two frameworks, the method developed by researchers at the University of Jyväskylä is suitable for Step 1 and partly Step 2 of the SBTN framework.

The results of this study provide valuable insight into the biodiversity impacts of a research organization and what they are composed of. The results will allow us to identify areas of refinement in the methodology we use, which could provide more accurate information on the biodiversity impacts of specific procurements. The applicability of the biodiversity footprint method developed by researchers at the University of Jyväskylä also opens up new opportunities for organizations to adopt the SBTN framework.

Key words
Biodiversity footprint assessment, biodiversity loss, Science Based Targets for Nature

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Luonnon monimuotoisuuden väheneminen on yksi suurimmista ympäristöuhista. Luonnon monimuotoisuuden merkitys ihmisille, yhteiskunnille ja yrityksille on suuri. Siksi on tärkeää arvioida ihmisen aiheuttamia vaikutuksia luonnon monimuotoisuuteen ja sitä, miten niitä voidaan vähentää. Eri organisaatioiden luontojalanjälki voidaan arvioida luontokadon suorien ajurien perusteella. Tässä työssä lasketaan VTT:n luontojalanjälki Jyväskylän yliopiston tutkijoiden kehittämällä menetelmällä. Tavoitteenamme on arvioida VTT:n luontojalanjäljen kokonaissuuruus, mitkä ovat olennaisimmat sitä aiheuttamat toiminnot, miten luontojalanjälkeä voitaisiin pienentää ja mitä muita parannuksia voitaisiin tehdä. Työssä tarkastellaan myös käytetyn laskentamenetelmän soveltuvuutta Science Based Targets for Nature -viitekehykseen.

VTT:n luontojalanjälki vuonna 2022 oli yhteensä 105,73 nBDe, josta suurin osa syntyi kaukolämmöstä, yrityspalveluista sekä koneista ja laitteista. Mahdollisia toimia luontojalanjäljen pienentämiseksi ovat muun muassa biopohjaisten polttoaineiden osuuden vähentäminen energiantuotannossa, luontohaitta intensiteetiltään korkeiden tuotteiden ja palveluiden välttäminen tai minimoiminen ja haitallisten toimintojen volyymin vähentäminen. Organisaatiotason parannukset liittyvät talous- ja ympäristökirjanpitoon, mikä voisi auttaa rakentamaan tehokkaamman järjestelmän luontojalanjäljen arvioimiseksi tulevaisuudessa. Viitekehyksien vertailun osalta, Jyväskylän yliopiston tutkijoiden kehittämä menetelmä soveltuu SBTN-viitekehyksen vaiheeseen 1 ja osittain vaiheeseen 2.

Tämän tutkimuksen tulokset antavat arvokasta tietoa tutkimusorganisaation luontohaitoista ja siitä, mistä ne koostuvat. Tulosten avulla voimme tunnistaa menetelmän kannalta potentiaalisia parannuskohteita, joiden avulla voidaan saada tarkempaa tietoa tiettyjen hankintojen luontohaitoista. Jyväskylän yliopiston tutkijoiden kehittämän luontojalanjälkimenetelmän sovellettavuus avaa myös organisaatioille uusia mahdollisuuksia SBTN-viitekehyksen käyttöönottoon.

Asiasanat
Luontojalanjälki, luontokato, Science Based Targets for Nature

Säilytyspaikka
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CONTENTS

1 INTRODUCTION

Humankind is currently facing many environmental challenges, but biodiversity loss is unquestionably one of the biggest (IPBES, 2019). Biodiversity loss refers to the loss of species diversity, habitats, and loss and degradation of species populations (IPBES, 2019; Cardinale et al., 2012). Evidence of the severity and extent of biodiversity loss includes the fact that ecosystem extent and condition has been assessed to be declined globally to 47% of natural levels and about 25% of species in assessed animal and plant groups are at risk of global extinction (IPBES, 2019). Biodiversity loss is also a natural phenomenon, but current biodiversity loss is the result of an increase in the quantity and intensity of human activities (IPBES, 2019). Biodiversity loss is driven by indirect and direct drivers (IPBES, 2019).

Biodiversity plays an important role for people and our way-of-living. World Economic Forum list in its 2024 Global Risks report biodiversity loss and ecosystems collapse as one of the most severe risks over the next decade (World Economic Forum, 2024). Human thriving is the result of the use of nature's resources, which means that biodiversity creates value for people in many different ways. These can be called values of biodiversity or nature's contributions to people (NCP) (IPBES, 2019). The benefits created by biodiversity are crucial for human well-being and livelihoods, providing necessary environmental conditions for living, food, medicine, energy, clean water, resources, social and psychological value (Dasgupta, 2021). However, as a result of biodiversity loss, it is estimated that since 1970 to the present day, 14 of the 18 nature’s contributions to people categories have declined and only trends in agricultural production, fish harvest, bioenergy production and harvest of materials have increased (IPBES, 2019). Biodiversity and NCPs are also valuable for almost all businesses and organizations, whose activities are ultimately based on the opportunities created by biodiversity (Houdet et al., 2012). It is estimated that biodiversity loss threatens up to half of the world's gross domestic product (World Economic Forum, 2020).

Risks associated with biodiversity loss has led to international initiatives. The parties of the UN Biodiversity Conference in 2022, with adoption of the Kunming-Montreal Global Biodiversity Framework, reached an agreement on a global target to protect 30 percent of terrestrial, inland water, coastal, and marine areas. Additionally, the parties agreed that at least 30 percent of degraded terrestrial and aquatic ecosystems should be restored by 2030. (Convention on Biological Diversity, 2022) European union's Biodiversity Strategy has similar goals and aims to halt biodiversity loss and reverse its decline by 2030, including increasing protected areas to cover 30% of land and marine areas, placing at least one-third of these under strict protection, and enhancing management of all protected areas (European Comission, 2021).

Every organization today has environmental and biodiversity impacts that spread across the globe through global trade routes and supply chains (Presberger et al., 2023). To understand these global impacts, we need information about the production and consumption activities of the organization. Financial accounting provides a complete account of the consumption activities of any organization and can be used as a data for the assessment of the global environmental and biodiversity impacts. Financial accounting, combined with environmental accounting, provides companies with a tool to bring together two issues that are traditionally considered in separately. Researchers from the University of Jyväskylä (JYU) have developed five-step financial-environmental accounting framework that can be used to examine the carbon and biodiversity footprint of any organization, based on the financial accounts of the organization (El Geneidy et al., 2023). Carbon footprint calculations are common today but are not in themselves sufficient to solve or provide information on the simultaneous problem of climate change and biodiversity loss (Chen et al., 2021). Other methods to account for biodiversity loss have been developed in recent years (Crenna et al., 2020; Damiani et al., 2023; Sanye-Mengual et al., 2023), but researchers of JYU has taken a significant step forward in assessing global biodiversity impacts of any organization (El Geneidy et al., 2023). Method developed by researchers of JYU has been tested on case studies for very different organisations, including city of Tampere, University of Jyväskylä, Finland's public procurements, and SOK-group (El Geneidy et al., 2023; Pokkinen et al., 2024; Pokkinen et al., 2023; Pykäläinen et al., 2024; Peura et al. 2023). Biodiversity footprint assessment method developed by researchers at the University of Jyväskylä has proven itself to be scalable and applicable for many different organizations and considers upstream and global biodiversity impacts comprehensively in comparison to other assessment methods.

Simultaneously with the assessment methods, several disclosure standards for biodiversity have been developed in recent years (Lammerant et al., 2024; Tin et al., 2024). Science Based Targets Network (SBTN) has built five-step framework for cities and businesses to set targets and mitigate biodiversity impacts (Science Based Targets Network, 2024). Their goal is to change economic systems and protect global environment by meeting the demand for new methods, guidance and tools to create science-based targets for the environment (Science Based Targets Network, 2024). SBTN approach is to find the most material business activities that creates biodiversity loss pressure on the locations that are most vulnerable to these impacts (Science Based Targets Network, 2024). This enables organizations to set targets that are most likely” to bend the curve” on mitigation of biodiversity loss. However, we found a research gap in the literature regarding the integration of different biodiversity footprint methodologies and frameworks. Nature-related disclosures obligate organizations to disclose certain aspects, but often leave undefined and open the possible methods for conducting the assessment between the initial obligation and the final report.

Our main objective in this case study is to assess the biodiversity footprint of the VTT, Technical Research Centre of Finland (VTT, n.d.), using the assessment method developed by JYU researchers. VTT is one of Europe's leading research institutes and owned by the Finnish State and its ownership steering is the responsibility of the Ministry of Economic Affairs and Employment (VTT, n.d.). Our research questions regarding the biodiversity footprint of VTT are: what is the biodiversity footprint of VTT? What are the most material business activities causing it? These thoughts raised further questions: how to mitigate the biodiversity footprint of the VTT? What organizational improvements could be made to better integrate biodiversity footprint assessment into VTT's annual reporting? In the second part of our work, we studied the applicability of the methodology developed by JYU researchers for the SBTN framework. Our research questions were: to what extent is the methodology developed by JYU researchers applicable to the SBTN framework? Does the method meet the data and tool requirements set by SBTN? What are the common features of these two frameworks?

First, we present the theoretical background about biodiversity, it’s contribution for the humankind and biodiversity loss and its drivers. We will also explain the implications of biodiversity loss for business and what frameworks, standards, directives and biodiversity footprint methodologies have been developed. Secondly, we will open the methodology we used to assess the biodiversity footprint and benchmark the frameworks. Third, we review the results of both the biodiversity footprint and the comparison of the frameworks. Finally, we will discuss the most relevant results of the biodiversity footprint, what can be done to mitigate it, what organizational improvements could be made and what limitations were associated with our study. We will also discuss the suitability of the methodology developed by JYU researchers to the SBTN framework, how it meets the requirements for data & tools defined by the SBTN and what other similarities exist between the two frameworks.

2 BIODIVERSITY

Biodiversity is a term in biology that refers to the diversity of living nature, covering all organisms, their genes and different ecosystems (Verma, 2016). Biodiversity is divided into three subcategories: genetic, species and ecosystem diversity (Verma, 2016). Biodiversity is currently in crisis, with dramatic declines at all levels (IPBES, 2019). At the same time, biodiversity is extremely important to humanity in many different ways, posing challenges to sustainability. Human-caused biodiversity loss is one of the greatest challenges of our time, requiring massive action to minimize irreversible impacts.

2.1 Levels of biodiversity

Genetic diversity is the diversity of genes within a species that are passed on from one generation to the next (Verma, 2016). Genetic diversity is the starting point for biodiversity, as genetic variation is necessary for speciation (Ellegren & Galtier, 2016). Genetic diversity is also important for the survival of species. Changes in the environment pose challenges to species, and genetic diversity helps species adapt to these changes through natural selection (Vellend & Geber, 2005). In order to maintain genetic diversity, it is important that the same species has several different populations to prevent genetic homogenization (Ellegren & Galtier, 2016).

Species diversity describes the number of species in a given region (Verma, 2016). In practice, this refers to the variation in a species population or between different species in a given ecosystem. Of the different levels of biodiversity, species diversity is most often used to describe biodiversity (Daly et al., 2018). All species play a role in an ecosystem, so their abundance is an important indicator of diversity.

The third level of biodiversity is ecosystem diversity. An ecosystem is a community in which living nature (biotic components) interact with each other and with non-living nature (abiotic components) (Verma, 2016). Ecosystem-level biodiversity can often be referred to as community diversity. Ecosystem diversity therefore refers to the diversity of habitats, which includes different life forms

(Daly et al., 2018). A habitat is an organism or population of organisms in the place where they naturally occur (Verma, 2016).

2.2 Importance of biodiversity

Biodiversity is necessary for Earth and humans to sustain the life as we currently know it. Biodiversity is important for maintaining healthy and productive ecosystems that benefit people in countless ways. These can be called as values of biodiversity or nature's contributions to people (NCPs) (IPBES, 2019). Many NCPs are not fully replaceable, but some are not at all replaceable (IPBES, 2019). Thus, the importance of NCPs to humanity is paramount. In total of 18 NCP categories, 14 categories have shown decline and only trends in agricultural production, fish harvest, bioenergy production and harvest of materials have increased (Figure 1).

	Nature's contribution to people	50-year global trend	Directional trend across regions	Selected indicator
REGULATION OF ENVIRONMENTAL PROCESSES	1 Habitat creation and maintenance	↓ ↓	○ ○	• Extent of suitable habitat • Biodiversity intactness
	2 Pollination and dispersal of seeds and other propagules	↓ ↓	○ ○	• Pollinator diversity • Extent of natural habitat in agricultural areas
	3 Regulation of air quality	↘	↓↑	• Retention and prevented emissions of air pollutants by ecosystems
	4 Regulation of climate	↘	↓↑	• Prevented emissions and uptake of greenhouse gases by ecosystems
	5 Regulation of ocean acidification	→	↓↑	• Capacity to sequester carbon by marine and terrestrial environments
	6 Regulation of freshwater quantity, location and timing	↘	↓↑	• Ecosystem impact on air-surface-ground water partitioning
	7 Regulation of freshwater and coastal water quality	↘	○	• Extent of ecosystems that filter or add constituent components to water
	8 Formation, protection and decontamination of soils and sediments	↘	↓↑	• Soil organic carbon
	9 Regulation of hazards and extreme events	↘	↓↑	• Ability of ecosystems to absorb and buffer hazards
	10 Regulation of detrimental organisms and biological processes	↓ ↘	○ ○	• Extent of natural habitat in agricultural areas • Diversity of competent hosts of vector-borne diseases
MATERIALS AND ASSISTANCE	11 Energy	↗ ↘	↓↑ ↓↑	• Extent of agricultural land—potential land for bioenergy production • Extent of forested land
	12 Food and feed	↗ ↓	↓↑ ↓↑	• Extent of agricultural land—potential land for food and feed production • Abundance of marine fish stocks
	13 Materials and assistance	↗ ↘	↓↑ ↓↑	• Extent of agricultural land—potential land for material production • Extent of forested land
	14 Medicinal, biochemical and genetic resources	↘ ↓	○ ○	• Fraction of species locally known and used medicinally • Phylogenetic diversity
NON-MATERIAL	15 Learning and inspiration	↓ ↓	○ ○	• Number of people in close proximity to nature • Diversity of life from which to learn
	16 Physical and psychological experiences	↘	○	• Area of natural and traditional landscapes and seascapes
	17 Supporting identities	↘	○	• Stability of land use and land cover
	18 Maintenance of options	↓ ↓	○ ○	• Species' survival probability • Phylogenetic diversity

Figure 1. Global trends in NCPs from 1970s. 14 of 18 assessed categories show decline in their ability to provide nature's contributions to people (IPBES 2019, p. 23).

2.2.1 Consumptive use

Biodiversity is important for consumptive use values. Consumptive use values refer to things that can be harvested and consumed directly from the ecosystem (Verma, 2016). Especially in poorer countries, people still depend directly on food from the wild, such as game and wild plants (IPBES, 2019). Humans are also dependent on medicines from nature. At least 4 billion people are estimated to use natural medicines (IPBES, 2019). These include the antibiotic penicillin, produced by the *Penicillum* fungus and the antimalarial drug Quinine, derived from the bark of the *Cinchona* tree (Verma, 2016). Natural resources are also important for human energy use. Wood has been used to produce heat and energy since the dawn of time. Today, at least 2 billion people still use wood as their main source of energy (FAO, 2016a). The fossil fuels used today are also a product of biodiversity, as they are plants that decomposed and became fossilized millions of years ago (Verma, 2016).

2.2.2 Productive use

Productive use includes the production of bioenergy and many consumer goods and materials. These can be produced for example in biogas or bioethanol from basically any organic matter, such as manure, wood residues, straw and other by-products (Mahapatra et al., 2021). Other productive use products include many materials used in everyday life. These can include, for example, products from the forest industry, such as boards, plywood, and poles (FAO, 2016a). Other examples of products include animal horns and leather, silk from silkworm, wool, textiles, etc. (Verma, 2016).

Biodiversity is also important for the production of pharmaceutical material. Biotechnology is evolving at an accelerating pace that has led to the development of a new generation of medicines. Again, the key to this discipline is the diversity of nature, which can be harnessed for medical purposes through the development of molecular biology, nanotechnology, genetics, biochemistry and pharmacology (Alho, 2012). Many micro-organisms, plants and animals are useful as antibiotics, antivirals, antifungals and even for treating cancers (Alho, 2012).

2.2.3 Social, ethical, and aesthetic value

The social value of biodiversity encompasses ways in which human societies integrate nature and its diverse manifestations into their cultural, social, religious, and spiritual practices (Pretty et al., 2008). Biodiversity plays significant role in historical and cultural context. In today's secular world, these are no longer given so much value, but once they were part of everyone's everyday life and celebrations. Natural elements such as plants, animals, and landscapes served as symbols of fertility, renewal, and spiritual transcendence, forming the basis of religious beliefs, folklore, and ceremonial practices (Verma, 2016). Furthermore, nature has long served as a source of inspiration for artistic expression, music, dance, storytelling and for science through biomimicry (Pretty et al., 2008). Recognizing the social value of biodiversity holds implications for conservation and sustainable development policies, emphasizing the importance of preserving for example cultural landscapes (Verma, 2016).

The ethical value of biodiversity is based on the principle that all life is valuable in its own right (Dereniowska & Meinard, 2021). Fundamental principle is that all forms of life possess intrinsic value, independent of their utility to humanity. From an ethical standpoint, conserving biodiversity is not only for its own sake but also for the welfare and continuity of human societies (Dereniowska & Meinard, 2021). In future, biodiversity will play as crucial role as for us and therefore conserving it isn't just to mitigate our problems, but also for livelihoods of future generations.

The aesthetic value of biodiversity encompasses the enjoyment and enrichment derived from experiencing the diversity and beauty of the nature (Tribot et al., 2018). Aesthetic value manifests through activities such as eco-tourism and nature-based recreation, wherein biodiversity serves as the cornerstone of experiential value (Verma, 2016). Moving around in a diverse and natural environment is much more refreshing and comfortable than, for example, in an urban or heavily modified agricultural environment (Tribot et al., 2018). People travel and move long distances to enjoy diverse nature, which shows that biodiversity has an important aesthetic value.

2.2.4 Ecoystem service value

Biodiversity is linked to many different ecosystem processes: nutrient, matter and energy cycles (Clergue et al., 2005). The basic principle is that many different biodiversity pathways contribute to the stability of ecosystems, to which the saying could be applied: "don't put all your eggs in one basket". Stability can be enhanced by ecosystem resiliency and resistance. This can be referred to as ecosystem service value (or non-consumptive value) of biodiversity, where the ecosystem is not directly consumed for its products (Verma, 2016).

The main NCPs because of ecosystem services are regulating factors. These include air and water quality, water quantity, ocean acidification, climate and extreme weather regulation, pollination, soil erosion and formation regulation, nutrient cycling, and regulation of harmful organisms and biological processes (IPBES, 2019). These are often interlinked processes, but not linear in their effects (Cardinale et al., 2012). As a result, the function of these processes is not yet fully understood. However, it is clear that these NCPs are of great importance for humans. For example, regulating factors are essential for food production, but often biodiversity has been overshadowed by the greater, but in the long-term unsustainable production method. These regulating factors also play an important role in human living conditions and housing. Extreme weather conditions, floods, poor air and water quality, for example, are factors that reduce living conditions.

2.2.5 Scientific and evolutionary value

Biodiversity also provides scientific and evolutionary value. Biodiversity serves as an empirical data, offering a view into the evolutionary history of organisms and the mechanisms driving their diversification. By studying the distribution patterns, genetic diversity, and ecological interactions of species we get information on the processes shaping biodiversity over geological time scales (Verma, 2016). Studying ecological networks reveals ways in which species interdependently regulate ecosystem processes and maintain ecological balance. From nutrient cycling to energy flow, each organism occupies a niche, contributing to the resilience and stability of ecosystems (Alho, 2008). These insights are important for informing conservation strategies and mitigating the impacts of anthropogenic disturbances on natural habitats. By monitoring changes in species distributions and population dynamics, it's possible assess the resilience of ecosystems and devise adaptive management strategies to mitigate the impacts of environmental change (Alho, 2008).

3 BIODIVERSITY LOSS

It is clear that biodiversity is important and provides value in many different ways. Human living standards have risen globally thanks to more efficient food production, energy and material use. Today's human flourishing has come about through the intensive, effectively over-exploitation of ecosystems, which has led to a decline in biodiversity at an unprecedented rate in human existence (IPBES, 2019).

Biodiversity loss refers to declining of biodiversity on ecosystem, species or genetic level in a given area ranging from local habitat to whole biosphere of earth. Biodiversity loss is also a natural phenomenon, but the current decline in the Earth's biodiversity is caused by human disturbance. The impacts of human activities have caused major changes in terrestrial, marine and freshwater ecosystems, resulting in a loss of biodiversity that poses a serious threat to humanity. Overall, according to indicators, ecosystem extent and condition has declined by 47% from natural baselines (IPBES, 2019). In terrestrial ecosystems it is currently estimated that only 25% of global land area is close to or not significantly affected by human activities (Ellis & Ramankutty, 2008). In terrestrial ecosystems changes have concentrated on "hotspots" and natural habitats having more intensive biodiversity impacts (Hoskins et al., 2018). Overall, forests have declined 68% from the baseline of pre-industrial level, even though net rate of forest loss has halved since 1990s (FAO, 2016a). In marine ecosystems it was estimated in 2014, that only 3% of marine area is free from human pressure and over 40 % of oceans were heavily under multiple drivers in 2008 (IPBES, 2019). In freshwater ecosystems the impacts are perhaps the most radical, with approximately only 13% of the wetlands that existed in the 1700s are still existing in 2000s (Davidson, 2014).

Species level extinction rates are accelerating, and have resulted in several extinctions already. In the long term, the extinction rate is hundreds or thousands of times faster than the natural rate of extinction (Barnosky et al., 2011; Ceballos et al., 2015). About 25% of species in assessed animal and plant groups are at risk of global extinction, which could mean the extinction of up to one million species (IBPES, 2019). Habitat integrity in terrestrial ecosystems has declined by 30% relative to the natural baseline, resulting in 9% of terrestrial species being at risk of extinction in the long term; this translates to 500,000 species (IPBES, 2019). Since the 1970s, 40% of vertebrate species populations in terrestrial ecosystems have declined (IPBES, 2019). Marine ecosystems have already undergone major changes, with living coral reefs almost halved in 150 years (Eddy et al., 2018). In marine ecosystems, more than 40% of amphibian species and a third of reef-forming corals, sharks and marine mammals are threatened (IUCN, 2018). In freshwater ecosystems, 84% of vertebrate populations have declined since 1970 (IPBES, 2019).

Biodiversity loss occurs at all levels of biodiversity. At the community level, changes occur in both natural and managed systems. Natural local ecological communities have undergone major changes due to human activity. Community composition has changed such that naturally occurring species in local terrestrial ecosystems have lost 20% of their original abundance (Hill et al., 2018). In particular, large species that are habitat demanding, carnivorous and slow growing are disappearing from many areas (IUCN, 2018). These include apes, sharks, big cats and tropical hardwood trees. On the other hand, many species are becoming more successful. These include species with the exact opposite characteristics of those that are disappearing, and especially invasive species have become more common; invasive species have increased by 70% since 1970 (Pagad et al., 2015).

In managed ecosystems changes are also occurring. There has been a dramatic shift in the distribution of plants used for food production. This has led to a situation where the number of local varieties and breeds of domesticated plants and animals and their wild relatives has been reduced rapidly (IPBES, 2019). Decline in the gene pool variation is a result of this and poses a threat to food security (IPBES, 2019). At the same time, wild relatives of domesticated species have been weakened and are again out of genetic selection, thus threatening agricultural resilience to disturbances such as climate change, pathogens and pests.

Human impact also has implications for rapid biological evolution, the effects of which can be seen after only a few years (IBPES, 2019). This anthropogenic evolution causes changes in pathogens such as viruses, bacteria and agricultural pests. These changes are reflected in insecticide resistance due to the large number of pesticides in agriculture (Aktar et al., 2009). In fisheries, anthropogenic evolution is reflected in the faster development of young to reproductive age due to intensive fish farming (IPBES, 2019). Climate change favors plants with an earlier growing season or will alter plant reproduction earlier (IPBES, 2019). Impacts can be both negative and positive, which can mean that adaptation to human impact is possible. As a result of biodiversity loss only 4 out of 18 NCPs is increased, which are agricultural production, bioenergy production, fish harvest and harvest of materials have increased (IPBES, 2019).

3.1 Drivers of biodiversity loss

Biodiversity loss is driven by indirect and direct drivers. These drivers have intensified significantly over the last 50 years (IPBES, 2019). The demands for good quality of life, for people and societies, has intentional and unintentional impacts on nature. Indirect drivers are broadly speaking interactions between society and nature (IPBES, 2019). Factors that affect the indirect drivers can be categorized as: values, demographic, technological, economical, and governance (IPBES, 2019). These indirect drivers lead to the direct drivers of biodiversity loss. Most important of these are land and sea use change, direct exploitation, climate change, invasive alien species and pollution (IPBES, 2019). Land and sea-use change is the most important direct human caused driver of global biodiversity loss, with a relative impact of 30%, followed by direct exploitation (23%), climate change (14%), pollution (14%) and invasive alien species (11%). In this chapter we go through indirect and direct drivers of biodiversity loss.

3.2 Indirect drivers of biodiversity loss

3.2.1 Values

Values underpin the behavior of people and societies. Values evolve over time, influencing people's views and relationship with nature. Long-held values related to the appreciation of nature have experienced an increasing decline due to economic globalization (Beng-Huat, 1998). Because of economic globalization, values associated with human consumption are remotely influencing more distant ecosystems. Human consumption is often driven by people's perception of a good quality of life associated with material possessions (Agarwala et al., 2014). There have also been changes in values and lifestyles in local communities, leading to the abandonment of indigenous and local knowledge and traditional practices (Halmy, 2016).

Positive changes in values have also occurred. Environmental activism is surfacing, and the importance of nature is valued. Indigenous people see nature as part of their social life and not as a property to exploit (Lalander, 2015). In general, indigenous people have become more vocal in advocating for their rights and views (Baer, 2014). People's experience of a good quality of life has also gained new insights. Well-being is increasingly associated with people's experiences and connection with nature, as well as education, health, knowledge and skills, and happiness and satisfaction (Sterling et al., 2017).

3.2.2 Demographic

Population dynamics have a major impact on biodiversity loss. The world's population has doubled in the last 50 years, it continues to grow, and human life expectancy is getting longer (Roser et al., 2017). This will lead to an even greater demand for resources, especially for activities such as agriculture, which will need to be expanded but are already having serious impacts on biodiversity (IPBES, 2019). Demographic changes are also driven by migration and urbanization.

Migration is both a consequence and a driver of environmental change. Environmental conditions, such as extreme events or changing climate, may force people to move to new areas, thus improving the condition of the area from which they move (Hunter, 2005). In turn, areas to which people move may face more severe environmental pressures (de Sherbinin et al., 2008). Human capital, i.e. education, knowledge, health, capabilities and skills, are also relevant factors for biodiversity (IPBES, 2019).

3.2.3 Technological

Technological developments have had a significant indirect impact on biodiversity, both negative and positive. Traditional technologies have generally evolved over a long period of time. For example, agricultural and agroforestry methods are based on a broad understanding of complex ecological systems that have resulted in highly productive, diverse and sustainable production methods (Gadgil et al., 1993; Toledo & Barrera-Bassols, 2008). There have been major changes in technological methods. Especially in agriculture, the Green Revolution of the 1960s-1980s has brought about a significant increase in productivity as a trade-off with serious harm to biodiversity (Abramczyk et al., 2017). Innovations have also enabled positive development pathways. Technological innovations have often developed because of some deficiency. For example, the lack of clean water has led to better water purification methods and energy needs for more efficient systems (IPBES, 2019).

3.2.4 Economical

The economic structure has shifted from agriculture towards industry and services. Since 1950, population has increased 2.7 times and global material consumption has risen 3.7 times (Schaffartzik et al., 2014). These production-related changes have had significant impacts on biodiversity. Today, production is highly concentrated, for example, large corporations often have a larger revenue than individual countries. Trade routes and supply chains are now global, which means that the biodiversity impacts of organizations are also global (Sun et al., 2017). Displaced environmental impacts occur in other countries, in particular in developing countries (Lenzen et al., 2012). It should therefore be noted that the sustainability of one country may be based on the unsustainability of another.

3.2.5 Governance

Governance is one indirect factor affecting biodiversity. Governance is distributed at multiple levels, which can be addressed from local community coordination to global coordination. From a business perspective, many certification schemes have been developed to inform stakeholders as transparently as possible about the sustainability of products or services, environmental, biodiversity and social impacts (IPBES, 2019). Often these are voluntary, and their adoption is driven by consumer desire for certain practices, corporate brand reputation or political reasons (Bartley, 2007). Political reasons also include legislation that affects companies' activities. Legislation has a significant indirect impact on biodiversity (IPBES, 2019).

3.3 Direct drivers of biodiversity loss

3.3.1 Land and sea use change

Land use change is the largest global driver of terrestrial and freshwater ecosystem biodiversity loss (IPBES, 2019). Land use change is mainly caused by agriculture, forestry and urbanization. Currently, over half of the Earth’s surface is under cover types of anthropic origin only 25% of the Earth's surface is not significantly affected by human activity (Foley et al., 2005). The land currently cleared for plantations and grazing in exchange of agriculture is mostly in tropical ecosystems, which also have the highest biodiversity levels. Between 1980 and 2000, 100 million hectares of tropical forest have been converted to this use (FAO, 2016a). Crop production occurs in 12% (Ramankutty et al., 2008) and grazing in 25% of the world's ice-free area (FAO, 2018). It should be noted that agricultural land use is significantly linked to air, water and soil pollution, with significant negative impacts on biodiversity (IPBES, 2019). However, at the root of these is the fact that natural land has been converted to agricultural use.

Urbanization is a major driver of land use change. Urban areas have doubled since 1992, which is also causing land use change as natural areas are converted for housing, infrastructure and transport (IPBES, 2019). This change is accelerating in some regions of the globe, especially in developing countries. By 2050, it is predicted that 25 million km of paved roads will be added (IPBES, 2019). The construction of energy infrastructure is also causing significant changes to land use, including oil pipelines, gas pipelines and dams. Deforestation and habitat fragmentation are the most significant adverse impacts of urbanization and its intra-structure on biodiversity (IPBES, 2019). Urbanization also has significant social impacts, as these processes are often accompanied by land grabbing, population displacement and social disruption, often affecting indigenous people and local communities (IPBES, 2019). However, it is worth remembering that urbanization can also have positive impacts on the environment. Often, better infrastructure improves economic performance, efficiency and innovation, for example (IPBES, 2019).

Forestry is also playing a significant role in land use change. Harvesting and logging in forests caused a 290-million-hectare reduction in native forest cover between 1995 and 2015, while the number of planted forests increased by 110 million hectares (FAO, 2016a). Industrial roundwood harvesting has increased in developed countries. In many developed countries forest use is regulated, but still about 10-15% of trade supply comes from illegal timber harvests (Hoare, 2015). This is particularly damaging to state owner revenue and the livelihoods of rural people (IPBES, 2019).

In the seas, the most significant damage to biodiversity over the last 50 years has been caused by fishing (FAO, 2005; FAO, 2016b). Fishing has expanded globally into large areas, deeper waters and concentrated in the hands of large individual organizations. Up to a third of fish species are currently overfished, which means that in the long term, fishing at this intensity is not sustainable (FAO, 2005; FAO, 2016b). Around 70% of fish species are currently fished at maximum sustainable levels and only 7% of species are underfished (FAO, 2005; FAO, 2016b). Fishing in the oceans has caused harm to target species, non-target species and habitats (IPBES, 2019).

3.3.2 Direct exploitation

Another major driver of biodiversity loss is direct exploitation. This has doubled from the 1980s to the present day, meaning that around 60 million tonnes of renewable and non-renewable resources are extracted annually (IPBES, 2019). Direct exploitation is driven by a significant increase in human consumption, including fossil fuels, plants, animals, ores and building materials. It is also underpinned by an increased human population, which has risen from 3.7 billion in 1970 to 7.6 billion today (Roser et al., 2017). Total gross domestic product is four times higher in developed countries than in least developed countries (IPBES, 2019). This means that the increase in consumption, the exploitation of natural resources, and the rise in economic and general living standards are unevenly distributed across the globe. Developing countries also face an increasing demand for natural resources, which poses challenges for how to reduce the damage to nature caused by direct exploitation.

3.3.3 Climate change

The third major driver of biodiversity loss is climate change. The impacts may not be as rapid as the other drivers, but changes are already being seen and in the long term this will put species under great pressure (IPBES, 2019). Climate change affects all levels of nature, from genes to ecosystems (IPBES, 2019). Ecological impacts can take the form of changes in the distribution of species, phenology, population dynamics, composition of species assemblage or changes in ecosystem functions and structure (Verma, 2016). Impacts are occurring in terrestrial, marine and freshwater ecosystems across the board and at an accelerating rate (IPBES, 2019).

The impacts of climate change on biodiversity are already clearly visible. It is estimated that around half of terrestrial threatened mammals (excluding bats) and almost a quarter of threatened birds may already be affected by climate change (IPBES, 2019). The impacts are also reflected in specific ecosystem types and areas. For example, taiga and tundra areas, which have not been directly affected to any significant extent in the past, have experienced negative changes (Settele et al., 2014). In these areas, large reductions and local extinctions of species have occurred on a large scale (IPBES, 2019). The impacts of climate change are often localized, even though they are global phenomena. Some local species are unable to adapt to a rapidly changing climate, which may be due to evolutionary or behavioral reasons (IPBES, 2019). The survival of these species also depends on their ability to disperse to new and more suitable habitats. Climate change is also having an impact on sea level rise, with island nations and their species particularly at risk (IPBES, 2019). Elevated carbon dioxide levels also contribute to ocean acidification, with localized impacts, particularly in shallow waters (Nikinmaa, 2013).

Greenhouse gas (GHG) emissions have doubled since 1980, which is also linked to a near doubling of consumption (IPBES, 2019). GHG emissions are therefore linked to many other drivers of biodiversity loss. Overall, 25% of global GHG emissions are driven by land clearing, crop production and fertilizers (IPBES, 2019). Of these emissions, 75% are from animal products (IPBES, 2019). Besides agriculture and consumption, the main sources of GHG emissions are energy (fossil fuels), travel and housing (Lamb et a., 2021).

3.3.4 Invasive alien species

Invasive alien species have a significant impact on biodiversity loss. Invasive alien species numbers have increased since 1970 by 70% per country (Pagad et al., 2017). In some island states, they may even be the most significant driver of extinctions (IPBES, 2019). The greatest harm is to native species, which are particularly abundant in island states. Invasive species can also cause harm on the mainland. For example, the pathogen *Batrachochytrium dendrobatidis* threatens up to 400 species of amphibians worldwide (Bellard et al., 2016). Invasive alien species result in biotic homogenization, which means that species already widespread spread further, taking up growing space and displacing native species (IPBES, 2019). The transformation of ecosystems into more homogeneous ones is harmful to ecosystem functions as well as to NCPs. The main cause of the spread of invasive alien species is humans, who accidentally or intentionally introduce species into new areas. Major drivers of invasions are higher human mobility, continuous habitat degradation, expansions of trade networks, and climate change (IPBES, 2019).

3.3.5 Pollution

Pollutants are a wide range of man-made harmful substances in the environment that also have significant impacts on biodiversity. Pollutants are generated because of human activity in a wide range of sectors. Pollutants generated on land leach into water bodies such as rivers, lakes and seas. Since 1980, plastic pollution has increased tenfold in the oceans (Jambeck et al., 2005). The harm of plastic macro particles is clear in the oceans, but the harm of microplastics and nanoparticles in food chains is not yet fully understood (IPBES, 2019). Coastal waters, in particular, are often heavily polluted. For example, they accumulate heavy metals and organic pollutants, mainly from industry, with serious consequences for species and ecosystems (UN-Water, 2015). Also, 80% of the world's wastewater is discharged into the environment without proper treatment (UN-Water, 2015). As a result, toxic sludge, solvents and other wastes also end up in the oceans. In total, between 300 and 400 million tonnes of contaminants end up in the oceans every year (UN-Water, 2015). In addition, large amounts of nutrients are leached from agriculture and wastewater are released into water bodies, resulting in hypoxia in water bodies (IPBES, 2019). These pollutants also harmful for human health (IPBES, 2019).

4 BIODIVERSITY, HUMAN ACTION, AND BUSINESS

As stated, human actions are causing significant biodiversity loss for the Earth. Current biodiversity loss poses unchangeable threats to the Earth system (Richardson et al., 2023). Biodiversity is an essential component of natural capital, providing many ecosystem services, including raw materials, production factors, and risk mitigation (Houdet et al., 2012). The so-called Dasgupta review states nature as “our most precious asset”, on which economies, livelihoods, and well-being of all depend on. (Dasgupta, 2021). The statement emphasizes that nature is not just in the background to human activity but is the base upon which societies and economies built on and it underscores the value of nature as an asset that is needed for sustainable life and the urgent need of protecting it.

This has wide-ranging implications on organizations and businesses. All businesses are intertwined with biodiversity, either directly or indirectly. There exists a reciprocal relationship between biodiversity loss and business activities, with the latter being a major contributor to biodiversity loss through activities such as habitat transformations and pollution (Houdet et al., 2012). Equally, biodiversity loss poses risks to businesses by altering resource availability and degrading ecological infrastructure (Houdet et al., 2020). Biodiversity-related risks to businesses cover ecological risks from biodiversity loss and ecosystem degradation, liability risks from compensation claims for biodiversity-related damages, and risks associated with achieving transformative change, including regulatory, market, and financial risks (OECD, 2019). This creates need for companies to identify their dependencies and impacts on natural capital to understand the risks. Business operations and value chains are closely linked to nature, with biodiversity loss threatening half of the world's gross domestic product (World Economic Forum, 2020). Practically all economic activities depend on ecosystem services, making biodiversity loss a concern for all businesses.

Environmental accounting encompasses processes and practices attempted to address and minimize impacts of organizations on the natural environment (Bebbington et al., 2023). Environmental accounting is activity that is carried out to (1) conservation of living things, (2) conservation of conditions that affect as a whole, such as global warming or depletion of ozone layer, and (3) conservation of resources (Taqi et al., 2021). Companies require accounting in carrying out the functions of collecting, calculating analyzing and reporting costs to manage environmental aspects to improve its environmental performance (Taqi et al., 2021). Environmental accounting is used to correct information gaps that arise because costs and environmental impacts aren't identified in support of business decisions (Taqi et al., 2021). The motivation behind environmental accounting is often organizational reputation management, internal factors, stakeholder pressure, environmental accidents, legislative demand, or the organization's existing environmental management system (EMS) (Mata et al., 2018). There has been challenges in biodiversity reporting, such as the scarcity of detailed and reliable information, the complexity of biodiversity issues, and the lack of standardized reporting practices (Boiral, 2016). Research on biodiversity accountability has been inadequate but number of studies have increased in the end of last decade (Boiral 2016; Vola & Gelmini, 2020; Roberts et al., 2021). Biodiversity accounting is not needed just for articulating the company's dedication and qualitative details, but also assessing performance in this realm through potential estimations (Boiral, 2016). In recent years this need for accounting biodiversity has resulted in biodiversity and nature focused disclosures, frameworks and standards (Lammerant et al., 2024; Tin et al., 2024)

4.1 Biodiversity disclosure approaches

Environmental accounting, disclosure, and reporting practices have been set by several standards like Global Reporting Initiative (GRI), European Sustainability Reporting Standards (ESRS) and International Sustainability Standards Board (ISSB). Frameworks can be thought as a set of principles providing guidance and shaping people's thoughts how to think about a certain topic (Tin et al., 2024). Recognition of the importance of the biodiversity for businesses has increased and so has the demand for the disclosure of the corporate biodiversity performance (Tin et al., 2024). This can be seen by several voluntary and regulatory biodiversity disclosure frameworks and standards. In this chapter we'll go through nature-related assessment and disclosure approaches.

4.1.1 European Sustainability Reporting Standards

European Sustainability Reporting Standards (ESRS) section E4 is regulatory standard on biodiversity and ecosystems. It is part of the Corporate Sustainability Reporting Directive (CSRD) set by European Commission (EFRAG, 2022). Companies that are subjected must report environmental, social and governance sustainability related information according to the ESRS (EFRAG, 2022). More detailed objective of this standard is to enable user of the sustainability statement to understand how the company affects biodiversity and ecosystems (Lammerant et al., 2024). This takes into account material positive and negative, potential and actual impacts, on drivers of biodiversity and ecosystem loss and degradation (EFRAG, 2022). Companies also must disclose actions taken to mitigate material actual and potential impacts on biodiversity, protect biodiversity and address risks, dependencies and opportunities and their short to long-term financial effects for the company (Lammerant et al., 2024). ESRS E4 takes into account planetary boundaries, Kumming-Montreal Global Biodiversity Framework and its goals, EU Biodiversity Strategy 2030, and EU birds, habitats and marine strategy directives (EFRAG, 2022). Companies have to disclose plans how they are going to adapt their strategy and business in line with these (Lammerant et al., 2024). This directive phases in on steps starting in financial year of 2024 (EFRAG, 2022). ESRS E4 is also aligned with TNFD and GRI standards (Lammerant et al., 2024).

4.1.2 Taskforce on Nature-related Financial Disclosures

Taskforce on Nature-related Financial Disclosures (TNFD) is a voluntary framework created for companies, public authorities and financial institutions of all sizes to identify, assess, manage, and to disclose nature related issues (TNFD, 2023). TNFD is a government-supported global initiative, and the Taskforce consists of 40 individual financial institutions, corporates and market service providers. In total, 14 recommended disclosures have been set and the conceptual foundation consists of general requirements and a set of recommended disclosures around four pillars: governance, strategy, risk & impact management and metrics & targets (TNFD, 2023). TNFD provides cross-sector and sector specific guidance (Tin et al., 2024). TNFD follows LEAP framework to approach organization's nature impacts which follows steps: locate, evaluate, assess and prepare (Lammerant et al., 2024). However, like other biodiversity frameworks, TNFD doesn't specify biodiversity separately from other "nature" (Lammerant et al., 2024). Concept of nature consists of four realms land, atmosphere, ocean and freshwater and biodiversity is recognized as an integral and essential part of the nature (Lammerant et al., 2024).

4.1.3 GRI 101: Biodiversity

Global Reporting Initiative (GRI) has created GRI 101: Biodiversity 2024 voluntary standard for organizations to publicly disclose its most significant impacts on biodiversity and how it manages them (GRI, 2024). The standard was created on multi-stakeholder process and was made up of leading experts and practitioners on biodiversity (GRI, 2024). The standard is usable for any organization, and it also has sector specific standards (Tin et al., 2024). GRI biodiversity standard is also align with TNFD and has adopted elements from it, for example, LEAP approach, same ecologically sensitive areas, alignment to five direct drivers of biodiversity loss and measurements to the state of biodiversity (Lammerant et al., 2024).

4.1.4 Science Based Targets Network

Science Based Targets Network (SBTN) has created target setting framework for biodiversity. SBTN is built for organizations to set targets on biodiversity to mitigate impacts and create positive environmental outcomes with science-based approach (Science Based Targets Network, 2024). We will introduce the SBTN framework in more detail at the methods section.

4.2 Biodiversity footprint assessment

A biodiversity footprint is the impact on global biodiversity caused by the production and consumption activities of a commodity, company, person, or community, influenced by factors such as greenhouse gas emissions, water use, pollution, and land use (IEEP, 2021). Measuring biodiversity footprints is needed for informing policy targets, natural capital accounting, ensuring sustainable resource use, assessing sectoral and global impacts, evaluating trade and development cooperation policies, guiding financial and private sector activities, and monitoring progress on biodiversity-related Sustainable Development Goals (IEEP, 2021). Biodiversity footprint assessment methods are still relatively scarce, but their development has taken significant steps forward in recent years (Crenna et al., 2020; Lammerant et al., 2022; Damiani et al., 2023; Sanye-Mengal et al., 2023). Growing interest in biodiversity related issues and emergency of disclosure frameworks are further encouraging the development of new assessment methods. Many of the developed biodiversity footprint assessment methods are built to assess site specific impacts, financial organizations' impact or other sector specific impacts (Lammerant et al., 2022; Daminiani et al., 2023). However, methods that are scalable for a larger spectrum of organizations, takes into account upstream impacts and all of the ecosystem types are still rare. One of these are method developed by JYU's researchers (El Geneidy et al., 2023), which will be introduced thoroughly in method chapter. In this chapter we'll look into similar kinds of biodiversity footprint assessment methods as JYU's that are developed.

4.2.1 University of Oxford Biodiversity footprint assessment

University of Oxford has carried out biodiversity footprint assessment as part of their sustainability strategy where they have set one goal to achieve "biodiversity net gain" (Bull et al., 2022). The framework aims to provide a systematic approach to identifying and addressing environmental impacts at universities. The study assessed environmental impacts of the university's activities, from research to education and operations. For categorizing the environmental impacts, Oxford defined a conceptual framework including five activities: travel, food, the built environment, the natural environment, and resource use and waste (Bull et al., 2022). Each of these features was associated with five general environmental impacts. The activities data was converted into mid-point environmental impacts, such as carbon dioxide emissions, land or water use, and air or water pollutants produced (Bull et al., 2022). To estimate the extent of biodiversity loss associated with these impacts, the midpoint impacts were converted into endpoint impacts using an established conversion methodology called ReCiPe (Huijbregts et al., 2017). The ReCiPe methodology calculates the proportion of local species that would be lost as a result of each activity, relative to the current number of species (Huijbregts et al., 2017; Bull et al., 2022).

4.2.2 Biodiversity Footprint Methodology (BFM)

Biodiversity Footprint Methodology (BFM) is developed by Plansup in collaboration with Wageningen Environmental Research (van Rooij & Arets, 2017). BFM utilizes GLOBIO model approach to link environmental drivers to the biodiversity impact (Alkemade et al., 2009; van Rooij & Arets, 2017). GLOBIO calculates local terrestrial biodiversity intactness and expresses this in mean species abundance (MSA) indicator (Alkemade et al., 2009). MSA describes biodiversity as the remaining mean species abundance relatively to their abundance in not human disturbed, pristine vegetation (Alkemade et a., 2009). MSA get values between 0-1, 1 indicating that area is completely in its natural state and 0,5 meaning 50% loss of the natural reference population (van Rooij & Arets, 2017). If the area is 2 ha and MSA 0,4, biodiversity footprint is: 2 ha x (1-0,4 MSA) = 1,2 MSA.ha. GLOBIO and therefore this method includes for terrestrial ecosystem following pressures: land use, infrastructure, fragmentation, climate change, and nitrogen deposition (Alkemade et al., 2009). For freshwater ecosystems: upstream land use, nitrogen and phosphorus deposition from air and water, dams and water management, climate change, and fishing (Lammerant et al., 2022). The method is possible to apply on global, regional, and national scale to determine changes in biodiversity caused by human activity (van Rooij & Arets, 2017). This method is usable for wide range of different organizations and have been tested on several case studies (van Rooij & Arets, 2017).

4.2.3 Corporate Biodiversity Footprint (CBF)

Corporate Biodiversity Footprint (CBF) is developed by Iceberg Data Lab (Iceberg Data Lab, 2023). This assessment method is developed to estimate company's biodiversity impacts throughout their value chain including company's direct biodiversity impacts (scope 1), the impact of its electricity suppliers (Scope 2) and its upstream and downstream impacts (Scope 3), adopting the taxonomy of the GHG protocol (Lammerant et al., 2022). The method considers four different biodiversity pressures: change of land-use, air pollution, climate change and water pollution (Iceberg Data Lab, 2023). Unit of biodiversity loss result is km^2.MSA (Lammerant et al., 2022). Starting input for the assessment is corporate activity based on their reported or modelled output. After this follows Life-Cycle Analysis to quantify the environmental pressures and last step is to calculate financial ratios for cross sectoral comparison. Iceberg Data Lab also provides biodiversity dependency, biodiversity positive contribution and biodiversity avoided impact scores (Iceberg Data lab, 2023) This tool is commercial and isn’t open source by its accessibility (Lammerant et al., 2022).

5 DATA AND METHODOLOGY

The methodology employed in our study is based on a framework developed by the researchers of the School of Resource Wisdom at the University of Jyväskylä (El Geneidy et al., 2023). This framework integrates various open, global databases and datasets and utilizes financial data from organizations and other relevant parameters such as megawatt-hours for energy consumption. To evaluate biodiversity, impact factors have been formulated to estimate both the geographical distribution and the extent of the potential damage incurred (El Geneidy et al, 2023). The method has been used for few studies, with cases including a university (El Geneidy et al. 2023), a student union (Pokkinen et al., 2023), a city (Pokkinen et al. 2024), public procurements (Pykäläinen et al. 2024) and a retailing cooperative organization (Peura et al., 2023). For the used method El Geneidy et al. (2023) list a five-step guide to conduct the biodiversity assessment, as Figure 2 suggest.

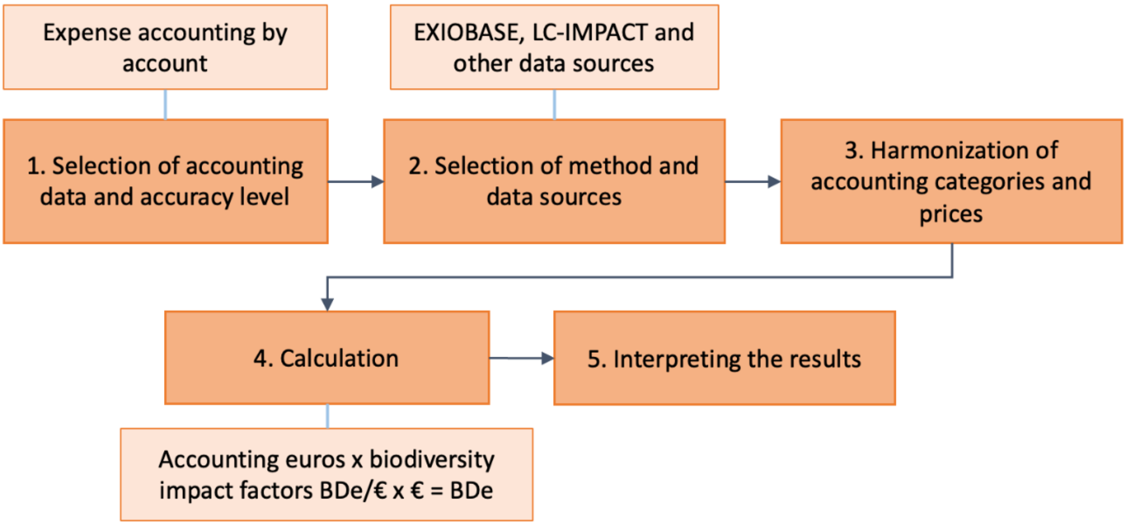

Figure 2. Steps for biodiversity footprint assessment for euro-based data. Based on El Geneidy et al. (2023)

Next four chapters go through the first four and delve deeper into the application of the methodology. Step 5 will be in this case the results chapter. The factors utilized in this study have been derived from several databases and were provided for us from the Biodiversity Footprint Team of JYU. We will go through the used databases and how the impact factors are formulated in chapters 4.1.2 – 4.2.4. All the calculations for this work were done with Microsoft Excel.

5.1 Biodiversity footprint: acquisition data calculations

5.1.1 Selection of accounting data and level of accuracy

For the study we were provided with data in various forms from VTT from year 2022. For organizations consumption of goods and services we utilized organizational acquisition data, which shared a light on money used for different purposes and VTT's categorization of its acquisitions. Acquisition data was from each of VTT's seven office locations. The data was specific to the level of an individual acquisition and every individual acquisition was linked to several head or substitutional categories. Highest level of head categories was labeled as "portfolio category", which referred to which type of operational role inside the organization (e.g Research services, HR) it was associated with. Additional to that, there are three subcategories. First, every acquisition was labeled under a certain account category based on what the acquisition type was. For example, all the mobilephones, were under the same account category "Mobilephones". Second, acquisition was characterized as a good, service or investment. Investments were a mixed category that had both goods and services. Acquisitions that covered all company level operations, like healthcare services and marketing expenses, were included in head office's data.

The data provided had limitations that should be noted. Acquisition data does not include all the smaller purchases made by employees. Business flights are not included in the provided data. Besides handling costs for hazardous waste, wastes are excluded from this study. Rents for office buildings are excluded form calculations, since the factor considers impacts that are associated with heating, electricity, and water use, which are calculated separately here. This avoids counting same impacts twice.

Acquisition data also included some procurements that could be associated with our calculations based on physical consumption. These include some motor gasolines, process water for research and electricity for a single building that has its own electricity contract. In terms of further categorizing, these could be assigned to results with calculations based on physical consumption. Here we opted out to keep these within the acquisition data results, since they are calculated based on monetary value.

5.1.2 Selection of method and data sources

The applied method combines different databases to create an impact factor for each product category and driver of biodiversity loss (El Geneidy et al., 2023). Here we go through what information these factors hold in them and how they can be formed.

Firstly, EXIOBASE database is used to assess direct drivers for biodiversity loss, and it enables the calculation of the environmental impacts associated with the consumption in Finland, measured in monetary units (El Geneidy et al., 2023), in this case euros. EXIOBASE is an environmentally extended multi-regional input-output database (EEMRIO) that provides comprehensive information on the environmental impacts associated with consumption activities, including their geographical distribution across the globe and by different industry sectors (Stadler et al. 2018). These impacts are assessed through direct drivers of biodiversity loss, for example land use (m2/€). The drivers include various aspects including land use across 15 categories, pollution across 5 categories such as nitrogen and phosphorus emissions, contributions to climate change, including emissions of carbon dioxide, nitrogen dioxide, and methane, and water utilization in different ecosystems (terrestrial, marine, freshwater) (Stadler et al. 2018; Figure 3). The database considers average impacts over the entire life cycle of products and services, including their production, manufacturing, packaging, and transportation phases (Stadler et al., 2018). EXIOBASE version 3.8.2. was used in formulating the impact factors, and it has data from 200 product categories across 44 countries and five broader regions (Stadler et al., 2021). Furthermore, EXIOBASE also provides information on how the environmental impact of product categories consumed in Finland is distributed globally by region (Stadler et al., 2023). Use of Pymrio, that is an open-source tool, allows determination of the distribution of nature impact caused by a specific product category across different countries (Stadler et al., 2021; Stadler et al., 2023).

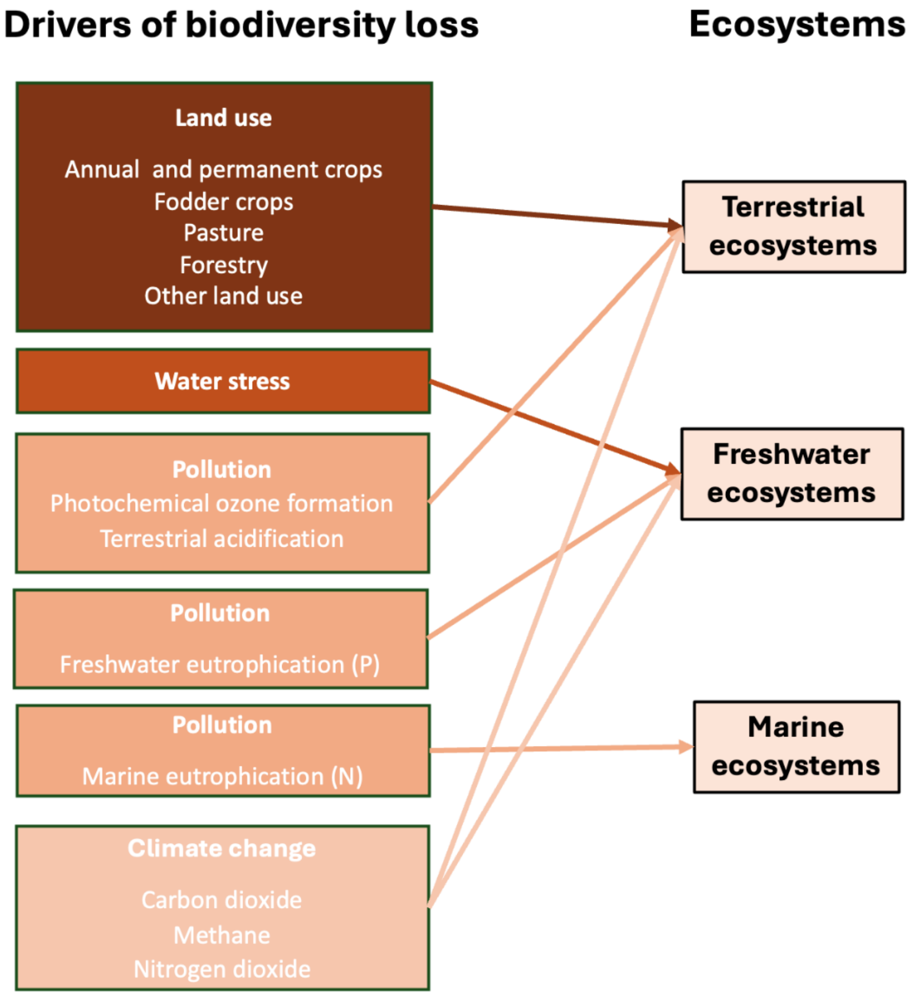

Figure 3. Drivers of biodiversity loss used in the biodiversity footprint assessment method developed by researchers of University of Jyväskylä. Based on El Geneidy et al. (2023).

Secondly, LC-IMPACT database is used to quantify the biodiversity loss resulting from environmental impacts caused by specific drivers (Verones et al., 2020). The measure for impact on nature used is the proportion of the world's species likely to disappear if harmful activities continue, known as Potentially Disappeared Fraction of Species (PDF). This measure is based on data and studies on species distributions and endangerment, as well as on species groups' sensitivity to different drivers of biodiversity loss (Verones et al., 2020)

LC-IMPACT database provides country-specific (244 countries) biodiversity impact coefficients for different drivers (244 countries), such as land use in PDF/m^2 (Verones et al. 2020). These coefficients indicate amount of nature impact caused by one unit of driver in different countries. Typically, biodiversity impact coefficients are highest in biologically rich areas near the equator (Verones et al., 2020).

The LC-IMPACT database offers a more detailed country-specific breakdown than the EXIOBASE database. For example, the environmental impact on the Africa region in the EXIOBASE database is distributed among the countries belonging to the Africa region in the LC-IMPACT database. The result is country-specific PDF/€ coefficients, the sum of which ultimately forms the global nature impact coefficient PDF/€ for a specific driver. Once this is done for all different biodiversity impact drivers, the nature impact coefficients for the same ecosystem are summed up, resulting in global nature impact coefficients for terrestrial ecosystems, freshwater ecosystems, and marine ecosystems in the form of PDF/€. (El Geneidy et al., 2023)

The background to nature impact on terrestrial ecosystems includes research on how different land use practices alter habitats, how climate change changes species' habitat distributions, and how soil acidification affects plant species diversity (Verones et al., 2020). Similarly, nature impact on freshwater ecosystems is based on information such as how water use reduces wetland areas, how climate change alters river flow, and how phosphorus causes eutrophication in water bodies (Verones et al., 2020). Nature impact on marine ecosystems is grounded in research on nitrogen fertilization effects in oceans (Verones et al., 2020).

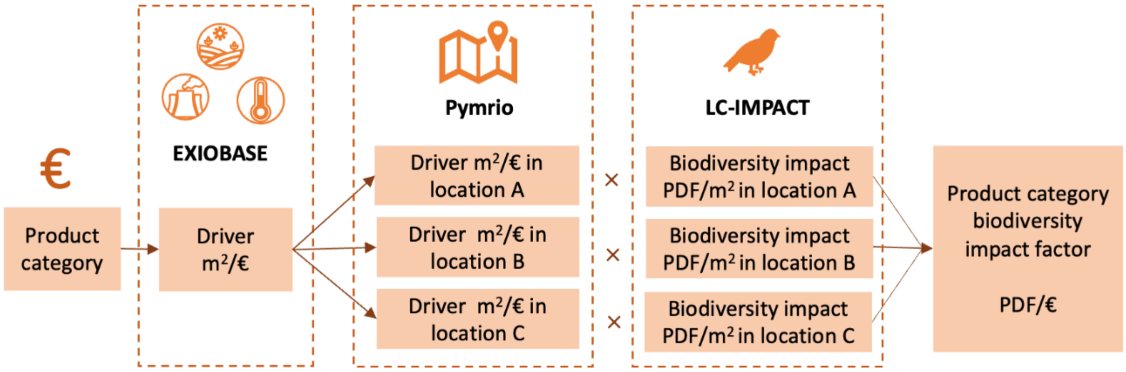

Figure 4. Formulation of biodiversity footprint impact factors using multiple databases. Based on El Geneidy et al. (2023) and Peura et al. (2023).

5.1.3 Harmonization of accounts

Every account category in VTT’s acquisitions was linked to the most suitable out of the 200 EXIOBASE categories. Here we had access to information to an individual acquisitions made with in that account category, of which we based the chosen EXIOBASE category. For instance, from the acquisitions the account category "Chemicals" included different research chemicals and it was associated with the EXIOBASE category "Chemicals nec" or the account category “Training of personnel”, which included different courses like first aid or occupational safety card training, for under “Education services”. Calculations were first done for each of VTT’s offices separately and results were combined after that. With this, the same account category can have multiple EXIOBASE categories associated with it, the difference being the office and what kind acquisitions were associated in their account category. This leads for more accurate results. It is noteworthy to state that the data related to individual acquisitions and linking them to an EXIOBASE category would give more accurate results. However, this process would be time-consuming, and in most cases, the category accounts could be unambiguously linked to a single EXIOBASE category. Also, EXIOBASE categories are limited, so for example all the chemicals use the same impact factor. Some category accounts encompassed a wide variety of acquisitions that could potentially be linked to multiple EXIOBASE categories. Nevertheless, the most appropriate category was selected to contain the entirety of the account. Here, it could have been possible to create factors based on existing ones, for example based on averages. However, current EXIOBASE categories that are "not elsewhere classified" (n.e.c) were suitable for this study. How acquisitions were categorized can be seen in Appendix 1.

Given that the acquisition data was sourced from the year 2022 while the EXIOBASE data is based on the year 2019, the acquisition prices needed adjustment to correspond to EXIOBASE prices. This was accomplished by subtracting the impact of inflation, as indicated by the consumer price index, from the prices of the accounting year 2022, utilizing product category- and year-specific inflation coefficients (Tilastokeskus, 2023a).

Furthermore, the acquisition euros represent what are known as purchaser prices, which includes all costs incurred by the buyer, including taxes, transportation fees, discounts, and excludes credit-related fees and penalties for delayed payments (Tilastokeskus, 2023b), whereas in EXIOBASE, they correspond to basic prices. The basic price for producers excludes taxes, includes subsidies, and incorporates transportation surcharges on the same invoice (Tilastokeskus, 2023c). The process of converting purchaser prices into basic prices requires considering product taxes, subsidies, trade and transport margins, as well as value-added tax. This conversion is facilitated through the utilization of a product category-specific price adjustment factor (El Geneidy et al., 2023). These adjustments culminate in reduced euro amounts utilized in calculations compared to those based on accounting prices. The final basic price for the calculations is determined as follows (El Geneidy et al., 2023):

$$BP = ACP - (ACP\ x\ INF) - (ACP\ x\ BPCF)$$

In which BP is basic price (€), ACP purchaser price from accounting (€) INF the inflation rate and BPCF the basic price conversion factor.

5.1.4 Calculation

After converting acquisition prices to reflect EXIOBASE prices, the biodiversity footprint caused by drivers in a unit of potentially disappeared fraction of species (PDF) for each ecosystem can be calculated using the formula (El Geneidy et al., 2023):

$$BF_{ecosystem} = BP_{account}\ x\ IF_{driver,EXIOBASE-category}$$

Here, *BFecosystem* represents the proportion of species in a given ecosystem (terrestrial, marine or freshwater) that are globally at risk of extinction if the pressure on nature remains constant over time (El Geneidy et al., 2023). It's important to note that biodiversity footprints in different ecosystems should not be directly summed (Verones, 2020), but rather each ecosystem can be weighted based on the estimated share of species within it compared to the total number of species globally (Roman-Palacios et al., 2022) to cover global biodiversity footprint (El Geneidy et al., 2023). The total biodiversity footprint can then be calculated as a weighted sum of biodiversity footprints for terrestrial, marine, and freshwater ecosystems (El Geneidy et al., 2023):

$$BF_{total} = BF_{terrestrial}\ x\ 0.801 + BF_{marine}\ x\ 0.102 + BF_{freshwater}\ x\ 0.096$$

Arguably, this unit can be referred to as biodiversity equivalent (BDe), representing the proportion of all species globally that are threatened with extinction if the impact remains constant over a time (El Geneidy et al., 2023). In essence, previously discussed PDF (Verones et al., 2020) is the same unit as BDe (El Geneidy et al., 2023). Similar to carbon dioxide equivalent (CO2e), which aggregates greenhouse gas emissions to assess their combined effect on the greenhouse effect, BDe integrates various drivers across different ecosystems into a single unit. As a ratio, BDe ranges from 0 to 1 and in previous studies made with the method, values have usually been very low (El Geneidy et al., 2023, Peura et al., 2023; Pokkinen et al., 2023; Pokkinen et al., 2024, Pykäläinen et al., 2024). This is due to studies focusing on a single organization and its footprint on global biodiversity loss. For scale, BDe value of 0.01 would mean that 1 % of the world species are threatened with extinction (Verones et al., 2020). Therefore, in this study, the results are presented in nano (10^-9) BDe.

Since the method can share a light on how biodiversity footprint distributes between countries, maps can be generated to show the approximal geographical distribution of pressures on nature globally (El Geneidy et al., 2023). This was done using country-specific impact factors for drivers of biodiversity loss. For visualizing, Microsoft Excel's Maps tool was used to generate biodiversity footprint maps.

5.2 Biodiversity footprint: physical consumption-based data calculations

Data for physical consumption-based calculations contained information on electricity, district heating, water and fuel consumption of VTT. For energy, water and company owned car's fuel use we had data that told the volume for consumption, e.g. MWh on energy use, cubes for water use and the type of fuel and driven kilometers for fuel use. Data for these is from VTT's internal sustainability reporting data. All these calculations were done in Microsoft Excel. We received data for waste in physical measures (kg) but their biodiversity footprint is excluded from the calculation due to lack of factors for physical consumption and shortcoming of monetary data. Here, compared to calculations done with the monetary value, factors have utilized the EcoInvent database (Wernet et al., 2016). The EcoInvent database has data on structure of supply chains, production inputs and their adverse impacts (Wernet et al., 2016). EcoInvent were utilized in life-cycle assessment (LCA) using the openLCA software. The life-cycle impacts were assessed with ReCiPe (Huijbregts et al., 2017). Drivers of biodiversity loss units are in form of physical consumption, such as land use caused by kilometers driven m^2/km.

5.2.1 Electricity calculations

Electricity contract and therefore the electricity spectrum of VTT were same in every office. Electricity's energy spectrum contained biomass 49%, wind 39% and, nuclear 12%. Each electricity source has its own biodiversity footprint factor BDe_{factor} in unit of BDe/kWh. We produced a single biodiversity footprint factor using the weighted average:

$$BDe_{electricity} = \frac{\sum_{i=1}^{n} BDe_i \times W_i}{\sum_i^n W_i}$$

Here BDe_{factor} represent each energy source's biodiversity footprint factor and W their weigh on the electricity spectrum.

Electricity consumption data were obtained in MWh, which were converted to kWh by multiplying the result by 1000. The data was also divided by office, whose consumption was summed up. After this we multiplied consumed MWh by biodiversity footprint factor for electricity and got final biodiversity footprint BF result for electricity:

$$BF_{electricity} = BDe_{electricity} \times kWh_{\text{total}}$$

5.2.2 District heating calculations

The data for district heating was also divided by office. Four of the offices used mixed district heating (Figure 5). We made the assumption that the energy spectrum of mixed district heat is similar to the average district heat spectrum of district heat in Finland. Finland's district heating spectrum data were from Motiva (Motiva.fi, 2024).

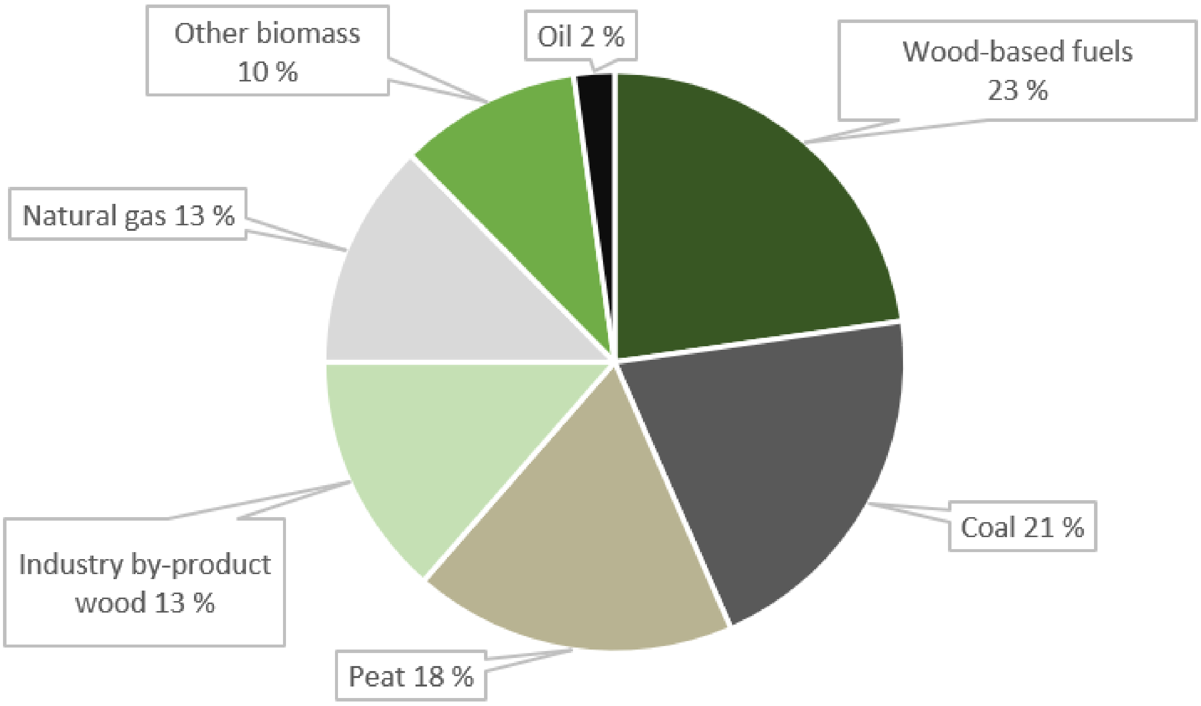

Figure 5. Energy spectrum of mixed district heating. Mixed district heating was used in four offices. Data obtained from Motiva (Motiva.fi, 2024).

Seven of the offices used green district heating energy (Figure 6). Green district heating was based on the mixed district heating spectrum, but the fossil energy sources, and peat were excluded, and waste heat was added to this.

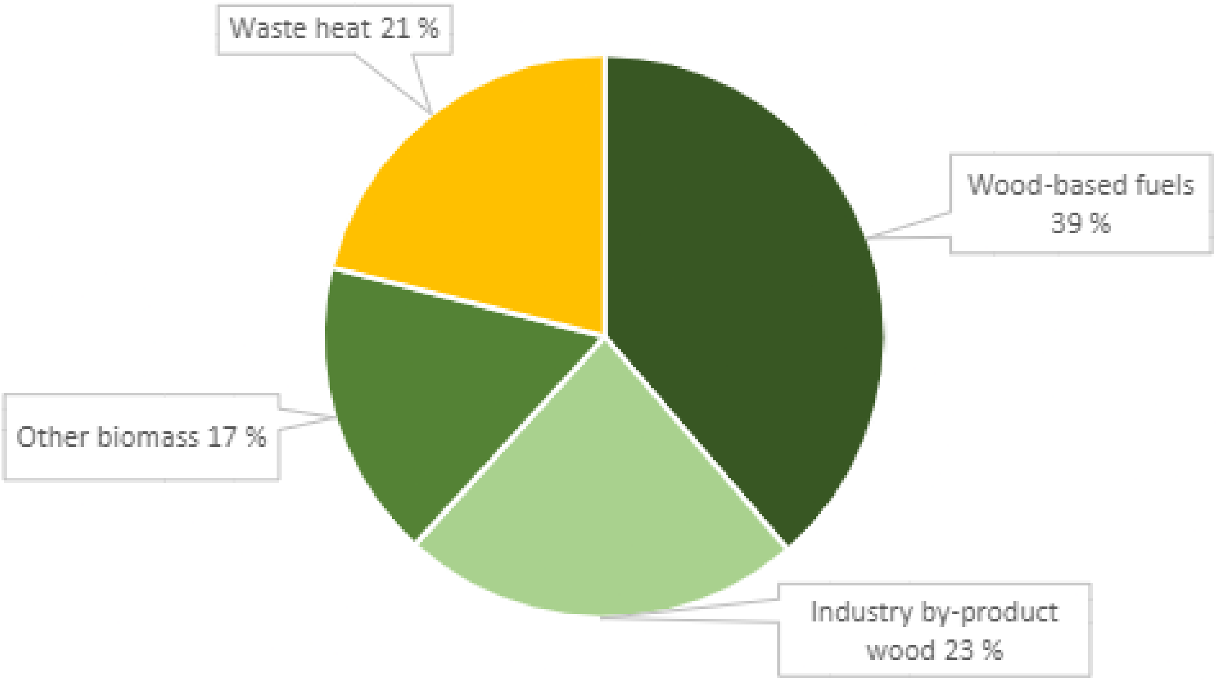

Figure 6. Energy spectrum of green district heating.

We calculated average biodiversity footprint factors for both district heating energy spectrums. We did this with a weighted average:

$$BDe_{heat} = \frac{\sum_{i=1}^{n} BDe_i \times W_i}{\sum_i^n W_i}$$

Here BDe_i represent different district heat source's biodiversity footprint factor and W their weigh on the energy spectrum of district heat.

We obtained two district heating factors in the unit BDe/kWh. District heating data were also obtained in MWh, which were converted to kWh by multiplying by 1000 for the calculations. We then summed up both the energy consumption of offices using mixed district heating MWh and did the same for offices using green district heating. We then multiplied the sum of the energy consumed for each energy distribution by its corresponding weighted average biodiversity footprint factor. The biodiversity footprint BF results were summed up to give the final biodiversity footprint of the district heating:

$$BF_{heat} = BDe_{green\ heat} \times kWh_{green\ heat} + BDe_{mixed\ heat} \times kWh_{mixed\ heat}$$

5.2.3 Water usage calculations

For water usage we used one biodiversity footprint factor in form of BDe/kg. Water usage data were obtained in form of cubic meters (m^3) of used water. We converted cubic meters into kilograms by multiplying the cubic meters consumed by 1000. Water consumption data was obtained by offices, where the amounts consumed were summed up. We then multiplied the summed consumption by the biodiversity footprint factor to get total biodiversity footprint BF of water usage:

$$BF_{water} = BDe_{water} \times kg_{water\ total}$$

5.2.4 Fuel calculations

Fuel consumption was obtained on a car-by-car basis. We used the kilometers driven by the cars as data. The VTT cars were gas, petrol, and diesel cars. We did not have a biodiversity footprint factor for gas cars, so they were excluded from the calculations. We summed the kilometers driven by petrol and diesel cars separately. We then multiplied the kilometers driven by the biodiversity factor for petrol cars (BDe/km) and the kilometers driven by diesel cars by their own biodiversity footprint factor. The BDe results were summed up to give the final biodiversity footprint of the fuels:

$$BF_{fuels} = BDe_{gasoline} \times km_{gasoline\ total} + BDe_{diesel} \times km_{diesel\ total}$$

5.3 Science Based Targets for Nature

The Science Based Targets Network (SBTN) has undertaken the task of developing methods to set targets at mitigating biodiversity impacts and creating positive environmental outcomes (Science Based Targets Network, 2024). SBTN has created a five-step framework to set targets. The five steps are: Step 1 Assess, Step 2 Interpret & Prioritize, Step 3 Measure, set & disclose targets, Step 4 Act, and Step 5 track. For biodiversity targets SBTN is still under development and only steps 1 and 2 are comprehensive. Steps 3-5 aren't explained as thoroughly on this paper due to lack of complete information.

5.3.1 Step 1: Assess

Step 1, Assess, involves the essential groundwork for understanding the existing biodiversity impacts of the organization. This phase necessitates a comprehensive assessment of the current state, including both direct and indirect impacts on biodiversity. The initial step is meant to be comprehensive insight on biodiversity impacts of organization and is considered the most extensive step of the five. The Step 1 is divided into two parts: 1a materiality screening and 1b value chain assessment (Science Bases Targets Network 2023a).

Materiality screening considers direct and upstream impacts of the goods and services but excludes downstream impacts (Science Based Targets Network 2023a). These impacts are connected to the five key pressures identified by the

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) that have been established as primary drivers of biodiversity loss globally. The purpose of the materiality screening is to identify which of the organization's operations are the most material in terms of biodiversity impacts, for which targets will be set in later stages (Science Based Targets Network 2023a). Materiality screening scores are rated from 1 to 10 for each driver, where 5 or higher means that a business operation is material to a driver (Science Based Targets Network 2023a). Materiality screening could be done by prescriptive or flexible approach. Prescriptive approach utilizes SBTNs own tools Materiality Screening Tool and High-Impact Commodity list. Flexible approach can be done in SBTNs highlighted listed tools or some other method which fulfils the requirements (Science Based Targets Network 2023d). Materiality screening is done to all of the upstream activities of the company.

Value chain assessment aims to estimate the main environmental and social impacts of an organization. Materiality screening is used to identify the issues that are likely to be most material. The amount of environmental impact of these activities and the exact location where they occur are then determined on value chain assessment. At this stage it is imperative to use primary data if available (Science Based Targets Network 2023a). Examples of this might be the amount of pollution entering the environment, carbon emissions, land use change etc. If primary data on the impacts of activities is not available, secondary data can be used, for example from a database (Figure 7).

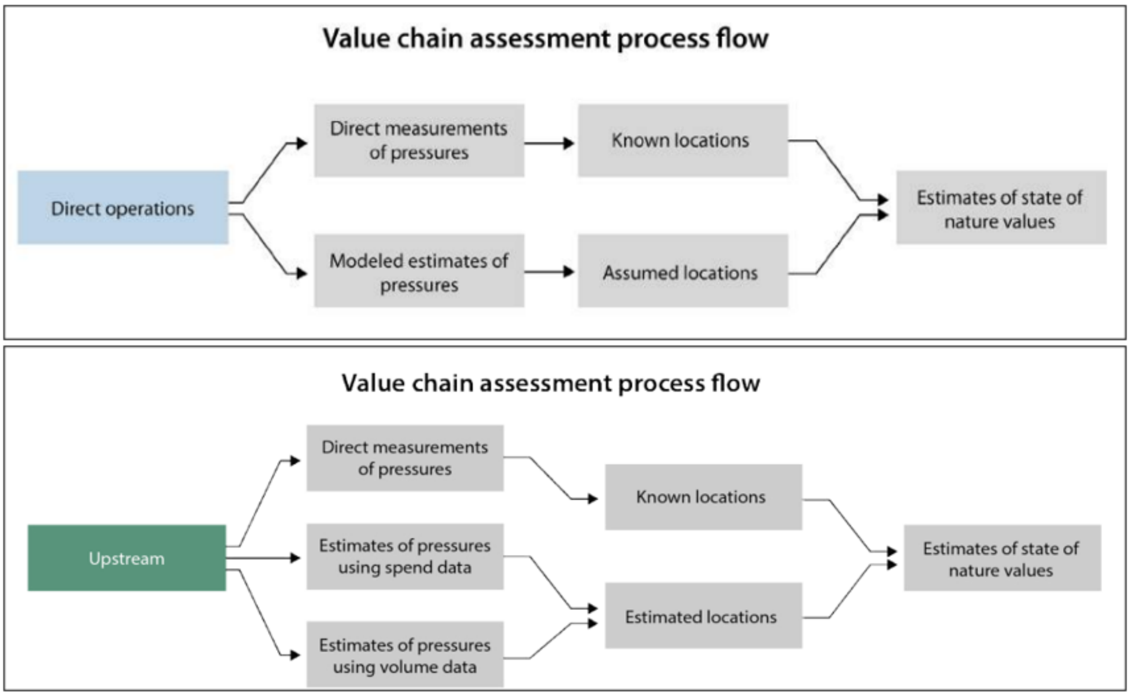

Figure 7. Process flow of value chain assessment on direct operations and upstream (Science Based Targets Network 2023a, 72-76).

In addition, information on the biodiversity (state of nature) where these pressures occur must be obtained. State of nature data is used to identify where pressures from activities are most harmful to local biodiversity (Science Based Targets Network 2023a). State of nature data needs two indicators: pressure-sensitive and biodiversity. Pressure sensitive state of nature indicators are appropriate to summarize the features of the state of nature most directly connected to the pressure being assessed. Biodiversity state of nature indicators are appropriate to estimate the state of nature in terms of biodiversity, along three key dimensions: the ecosystem, species, and genetic level. Value chain assessment has to be done for at least 67% of the material business activities.

5.3.2 Step 2: Interpret & Prioritize

Step 2 interpret & prioritize is meant to further prioritize the locations and business operations which to set targets. Goal of prioritization is to detect what has the greatest impact to "bend the curve", i.e. where the greatest positive impacts can be achieved. Step 2 starts by setting target boundaries, where direct operations and upstream are divided separately (Science Based Targets Network 2023b). Upstream activities may also often be under different management within the organization. Setting target boundaries makes it easier, as there is often a difference in spatial resolution and data availability and quality between direct operations and upstream activities. For example, usually for direct operations, precise coordinates of the site are already available.

Step 2 requires each pressure to be considered separately from the others. This means, for example, looking at land use, water use or pollution separately. For direct operations, this section requires sub-national spatial resolution, which can be at the landscape, ecoregion or basin level (Science Based Targets Network 2023b). For Direct operations, it is mandatory to consider all activities that are defined as being material in Step 1. Upstream activities are further divided into two different target boundaries, A and B. A target boundary contains upstream activities for which higher quality data are available and B contains lower quality data (Science Based Targets Network 2023b). For upstream activities, the country level spatial resolution is sufficient at Step 2. At Step 3, more detailed information on the location of the activity must be available.

After this, results are interpreted within the target boundaries and locations are ranked based on environmental impacts and social impacts. For example, if a location has significant environmental impacts and rich biodiversity, it will be ranked higher than a location with significant environmental impacts but less biodiversity (Figure 8). At this stage, social impacts are also taken into account, for example if the environmental impacts are also harmful to the local community (Science Based Targets Network 2023b). The ranked business operations and locations are then further interpreted in terms of economic feasibility and other co-benefits.

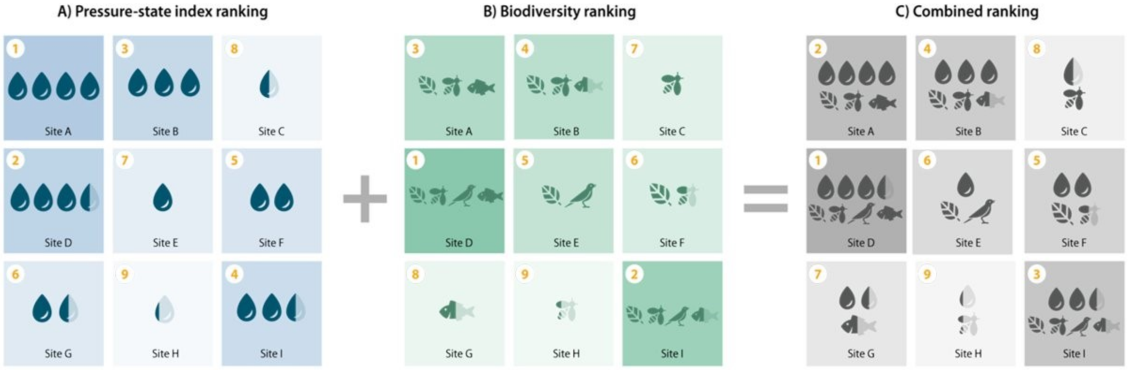

Figure 8. Location ranking from combining pressure-state-index and biodiversity data. Each water and animal icon represents significance of the state of nature indicator. Pressure-state-index and biodiversity index are combined to rank importance of locations to set targets on. On the each box's corner is the rank of location, for example site D on combined ranking is the most crucial location to set targets (Science Based Targets Network, 2023b).

5.3.3 Steps 3-5

Steps 3-5 have not yet been fully covered in the first versions of the SBTN. We present them briefly for this reason. Step 3 is called Measure, Set & Disclose. The previous steps have identified which activities are the most material and which activities have the greatest potential for "bending the curve" to mitigate biodiversity impacts (Science Based Targets Network 2023c). The main difference in Step 3 is the accuracy of the data. The purpose is to measure accurate baseline values and determine maximum allowable values, providing stakeholders with clear metrics and concrete targets (Science Based Targets Network 2023c).

Step 4, Act, entails implementing measures to achieve the targets set in Step 3 within the organization (Science Based Targets Network 2024). The SBTN framework advocates use of the Avoid, Reduce, Restore & Regenerate, and Transform mitigation hierarchy (Figure 9), emphasizing a multifaceted approach to biodiversity conservation (Moilanen & Kotiaho, 2021). This step necessitates the use of diverse indicators to monitor and report progress, reflecting the varied nature of mitigation activities. For instance, indicators for monitoring pollution differ significantly from those used for restoring and regenerating nature. Yet only limited information about this step is available and it will be completed in subsequent publications from the SBTN.

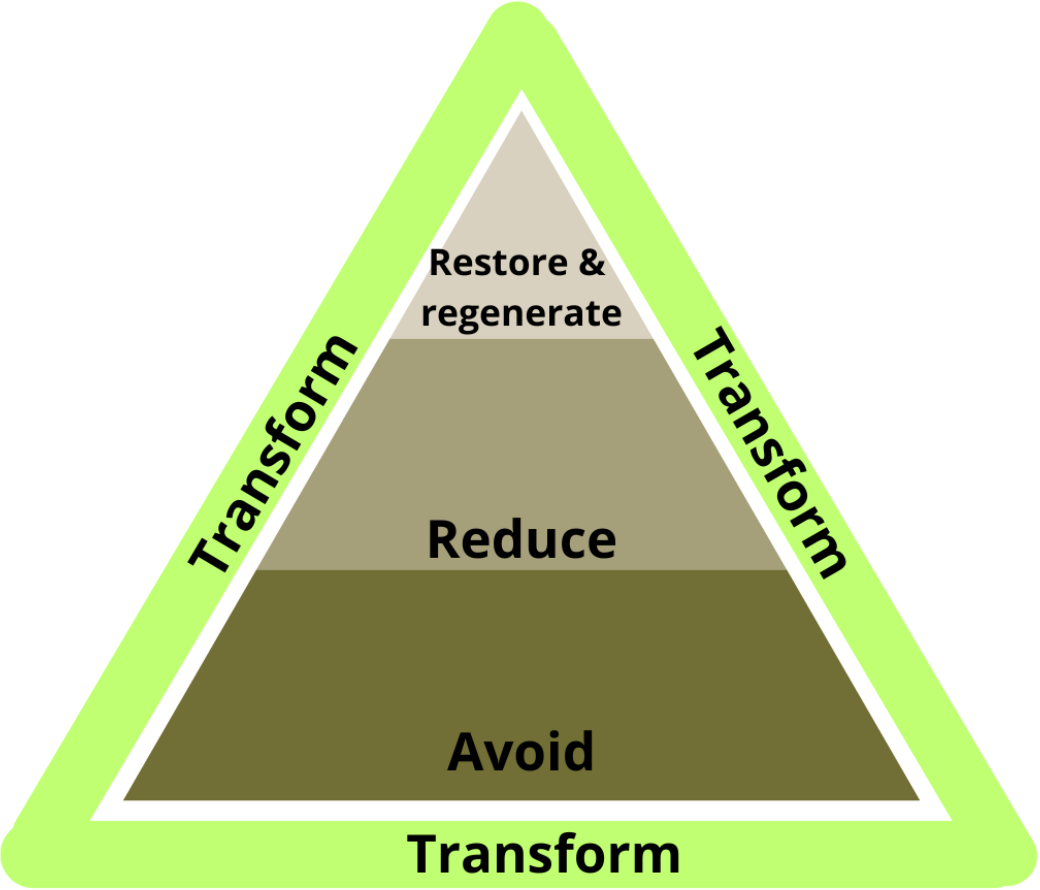

Figure 9. Step 4 mitigation hierarchy pyramid. Adapted from (Science Based Targets Networks, 2024).

Step 5 is called Track, which is basically related to each of the previous steps (Science Based Targets Network 2024). Measure, report & verify (MRV) related actions take place at each step of the process. The SBTN encourages public disclosure along the process. There is no specific guidance on MRV issues yet, which will be clarified in future publications from the SBTN.

5.3.4 Methodology: Comparison of SBTN and JYU method

The starting point for the comparison of the SBTN framework and JYU methodology has been to consult the SBTN technical guidance, the biodiversity short paper, tool & data requirements and other materials available on the website. The first aspect of the comparison has focused on the requirements of the tool & data and how the JYU method meets these (Science Based Targets Network 2023d). The tool & data requirement paper is expressed in writing, and this is supported by more detailed step by step technical guidance's. In addition, a list of non-SBTN methods that can be used in the process is provided. Based on this, we have reviewed and derived our own conclusions on the suitability of the JYU methodology for the SBTN framework. We have used cross tabulation as the methodology here, based on SBTN tool & data requirements. We have supplemented the tool & data characteristics and criteria table with information on how the JYU method applies to these. Three main criteria have been defined for tool and data: overarching data quality, pressure estimation and state of nature. The state of nature criteria includes both pressure-sensitive state of nature indicators and biodiversity indicators. These three main criteria are complemented by 8 categories of characteristics, including relevance, representative, spatial and temporal resolution, resource stability & preservation, accessibility, interpretability, coverage and authoritative & accurate.

We have also cross-tabulated other technical starting points that converge between the SBTN framework and the JYU methodology. The points of convergence have been examined in terms of scopes, pressure categories, data, coverage, state of nature indicators, materiality and what impacts are possible to report. This comparison is based on the Step 1 and 2 technical guidance and the biodiversity short paper. It is not yet clear how the JYU methodology will work in later Steps, but it is likely that Steps 1 and 2 are the most relevant at present. This is clear from the preliminary data available for the later steps, especially step 3.

There are still limitations to the review, the most important of which is the recentness of the SBTN framework and the fact that it has not yet been published in full. As a result, there are no practical examples of the SBTN framework being applied to an organization. The comparison is currently based on our best understanding of the framework and what similarities it has with the JYU methodology.

6 RESULTS

Results are divided on the basis of which assesments were conducted. First, we go through biodiversity footprint assessment results, secondly the geographical distribution of these, the pressures on nature and lastly the comparison of the STBN framework and JYU methodology.

Overall, VTT's biodiversity footprint in year 2022 for all acquisitions is 69.07 nBDe, 27.64 nBDe for district heating, 8.76 nBDe for electricity, 0.15 nBDe for water use and 0.11 nBDe for fuels (Figure 10). This totals the overall biodiversity footprint to 105.73 nBDe. In other words, this means that approximately 0.00001 percent of the world's species are threatened to go extinct, if current operations' impacts stay at the same level.

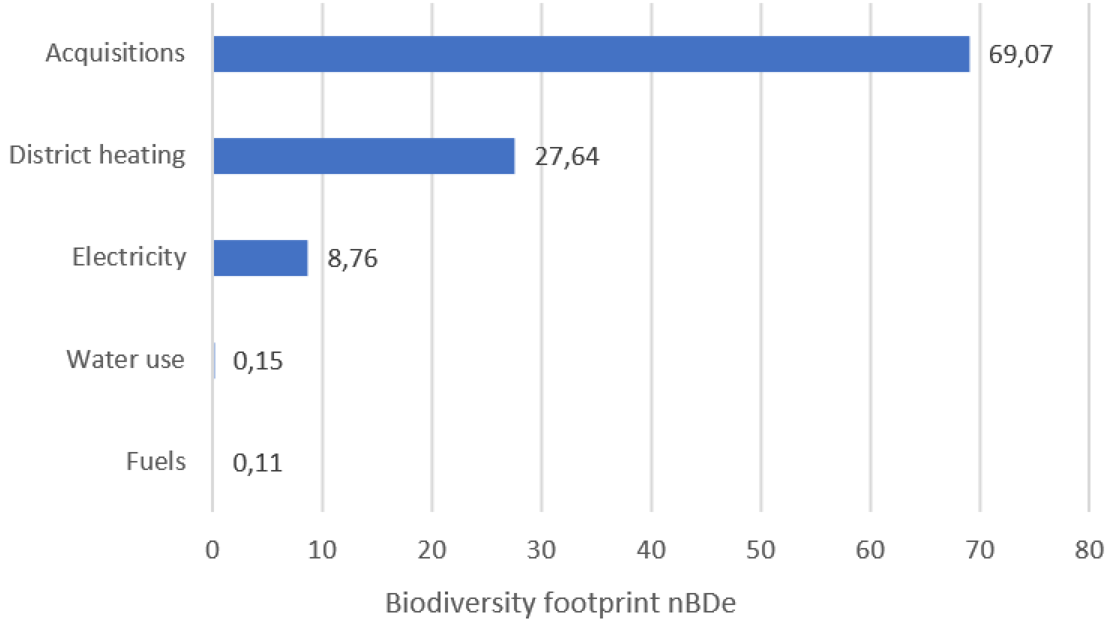

Figure 10. Biodiversity footprint (nBDe) of VTT.

6.1 Biodiversity footprint of VTT

Acquisitions here are categorized on the primary data. Based on VTT's own portfolio categorization of acquisitions, impacts are heaviest in materialistic/goods acquisition, with research equipment (17.11 nBDe) and materials (16.01 nBDe) being the top two (Figure 11). These are followed by research services (11.30 nBDe) and IT services for research (7.18 nBDe). These categories reflect the typical operations of VTT since it is a research organization. These are followed by general organizational operation categories of HR, Facility and infrastructure solutions.

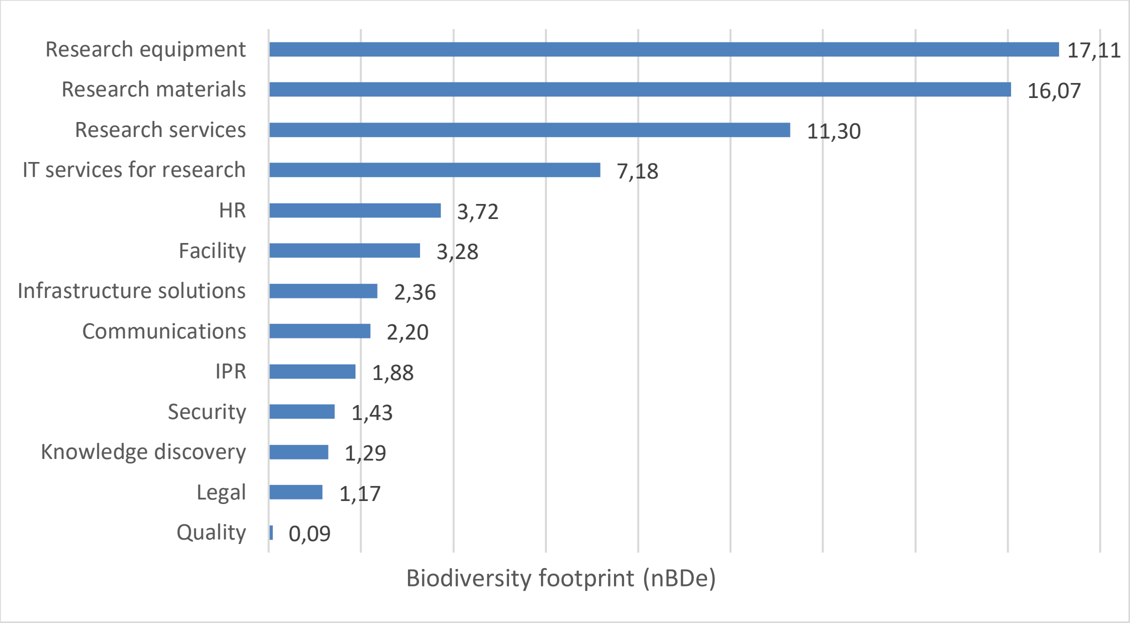

Figure 11. Categorization of impacts based on VTT's own portfolio categorization. Information on what portfolio categories include can be seen in Appendix 4.

When the portfolio category's share of total biodiversity footprint to share of category's total acquisition price, it can be seen that most impactful categories are also the ones that have the most expenses (Figure 12). Here Facilities make an exception since it includes the rents of office buildings while they are excluded from the footprint calculations.

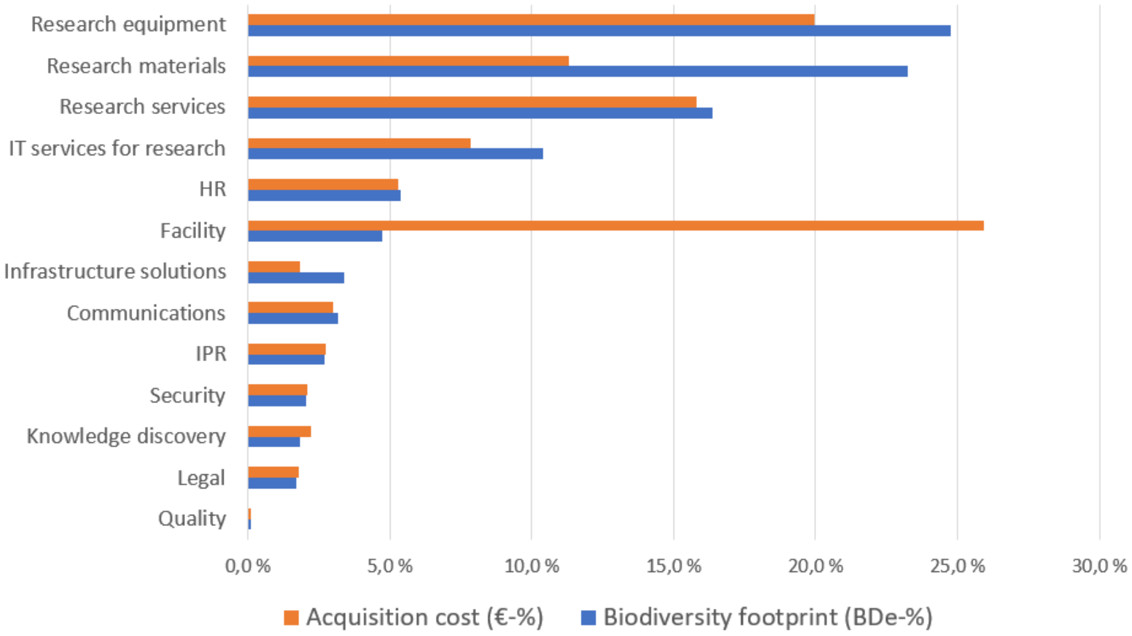

Figure 12. Results in VTT's portfolio categorization. Bars represent percentage of monetary volume and biodiversity footprint (BDe) of the portfolio category compared to the total volume and biodiversity footprint of VTT.

When looking at EXIOBASE categories instead of VTT acquisition categories, biodiversity footprint comes from "Other Business services", followed by "Machinery and equipment n.e.c" and "Furniture: other manufactured goods n.e.c" (Figure 13). All these categories include wide variety of acquisitions put under the most suitable EXIOBASE-category. Overall, the impacts landed across 38 EXIOBASE categories. Full list of EXIOBASE-categories and their biodiversity footprints can be seen in Appendix 2.

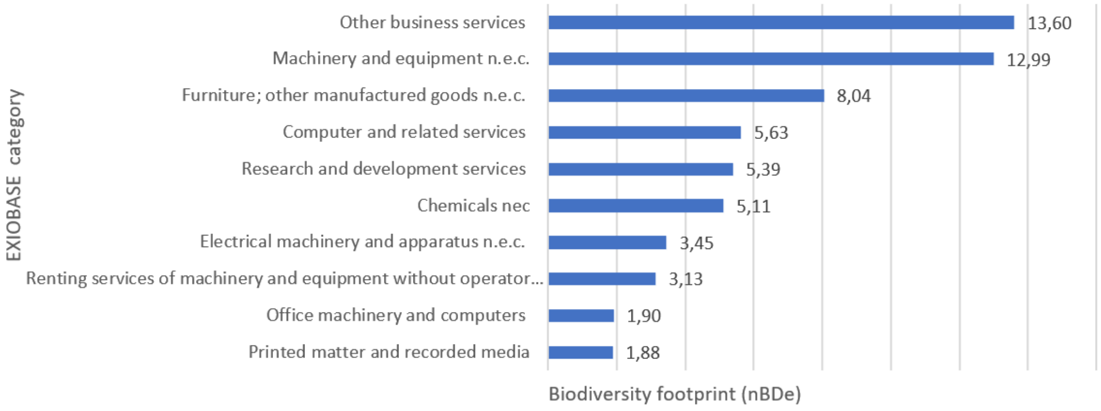

Figure 13. Biodiversity footprint (nBDe) results of 10 biggest EXIOBASE categories.

If again, this share of total biodiversity footprint is compared to acquisitions monetary value share, it can be that high acquisition values are followed by high biodiversity footprints. However, in some cases category's biodiversity footprint share exceeds the share of monetary value, which indicates that these categories are more intensive to the caused harm on biodiversity. These categories include “Machinery and equipment n.e.c”, “Furniture: Other manufactured goods n.e.c” and “Chemicals nec” (Figure 14).

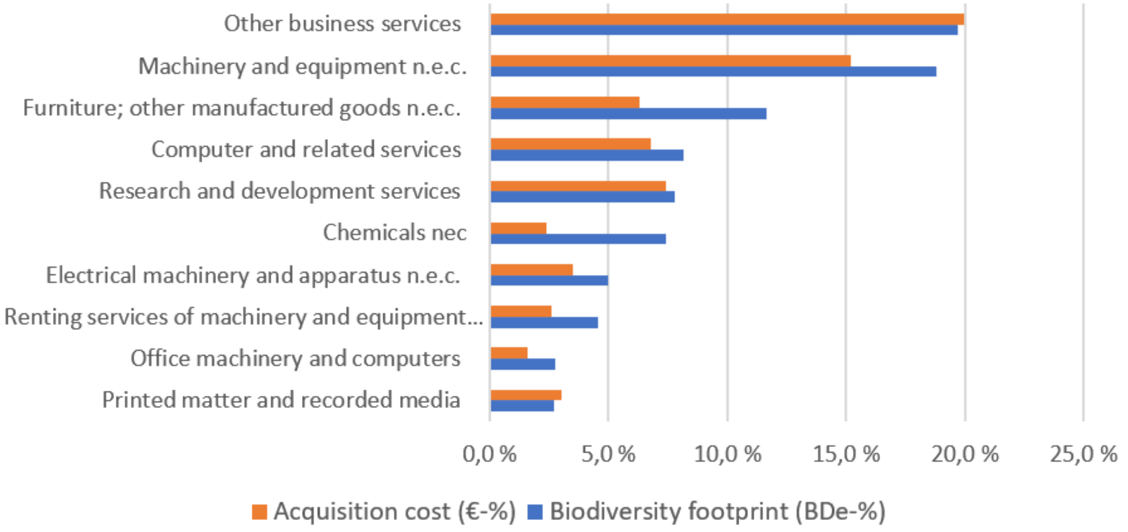

Figure 14. Results in EXIOBASE categorization. Bars represent percentage of volume and biodiversity footprint BDe of the EXIOBASE category compared to the total volume and biodiversity footprint of VTT

This relation between intensity on biodiversity loss and volume of monetary value can be looked through fourfold. This tool has been used to evaluate potential mitigation of biodiversity footprint categories that are high in intensity of the biodiversity footprint and high consumption volume (Pokkinen et al., 2024, Pykäläinen et al., 2024). In Figure 16, horizontal axis shows the volume of acquisition, in this case monetary value (€). Vertical axis shows the intensity of the biodiversity footprint, which is based on EXIOBASE category’s impact factors (BDe/€). Bottom right serves as the origo. Fourfold is formed by making linear lines for both axes based on the mean value. On the bottom corner, close to the origo, are categories that are low both in monetary value and biodiversity footprint intensity and the top left corner the opposite, high in both monetary value and biodiversity footprint intensity. Since monetary value had great variance, with the greatest categories being significantly bigger compared to the smallest categories, some categories were removed from the fourfold analysis. Top 28 EXIOBASE categories based on monetary value are included. Including the ten lowest categories would have weakened the readability of the Fourfold. Additionally, the monetary value increased by 30 % between categories 28 and 29, so cutoff point is justified. Interesting categories here (Figure 15) include “Chemicals nec” (9) and Furniture; other manufactured goods n.e.c” (5) with both high intensity and monetary volume, “Other business services” (1) and “Machinery and equipment n.e.c” (2) with high monetary volumes and intensity close to the median and “Motor Gasoline“(24) and “Oil/hazardous waste for treatment: incineration” (26).

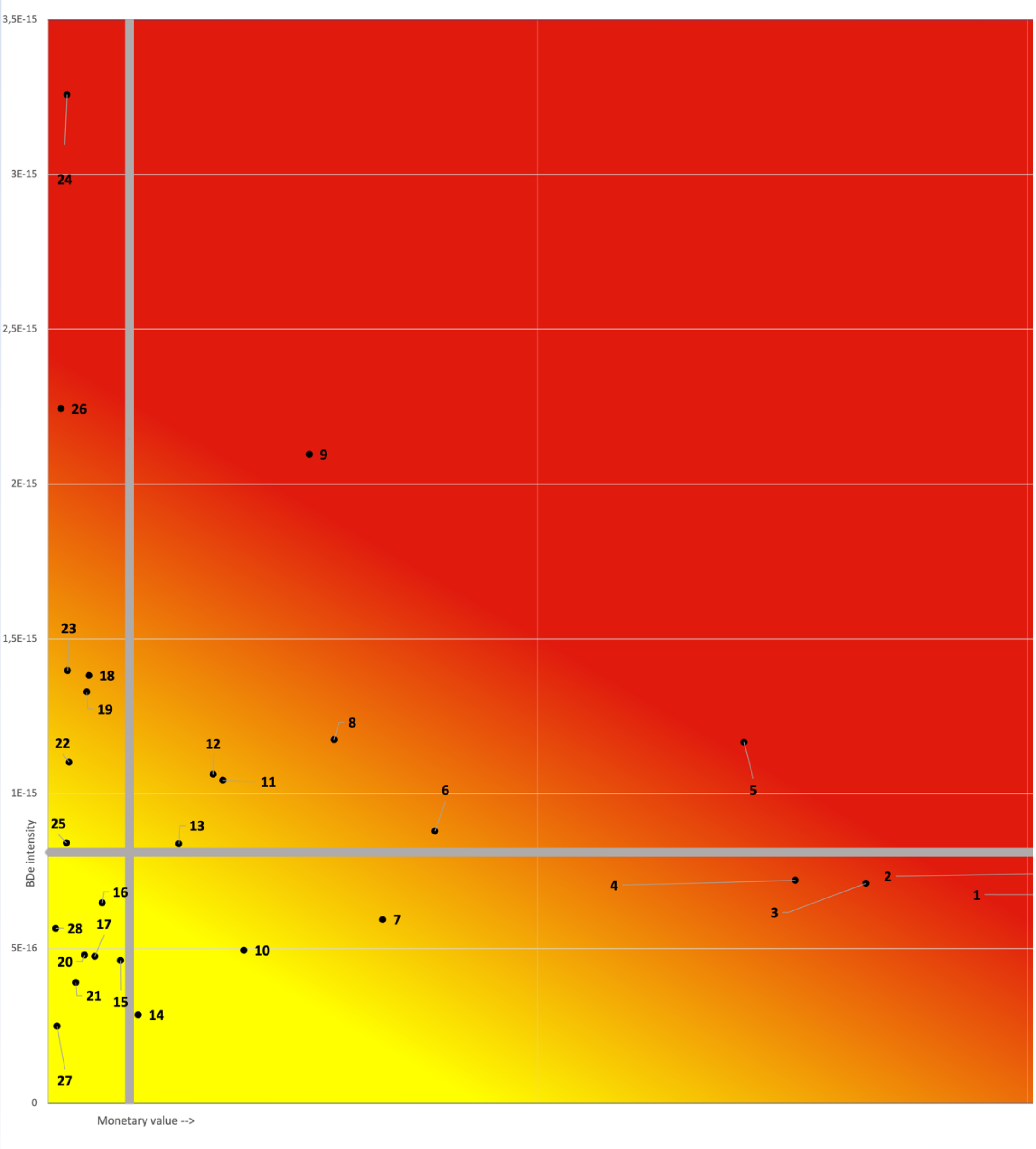

Figure 15. Fourfold, which shows categories that have high intensity of biodiversity footprint and high monetary value in top right corner, with the opposite being closer to the origo. Numbers represents EXIOBASE categories listed based on monetary value. Categories "Other business services" (1) and "Machinery and equipment n.e.c" (2) over exceed the figure, so for the readability they are cut off from the figure. For full image and list of EXIOBASE categories and their numbers are in the Appendix 2.

Acquisitions can also be looked on driver of biodiversity loss level for terrestrial and freshwater ecosystems. For marine ecosystems, only pollution is included. Terrestrial ecosystem drivers of biodiversity loss include climate change, land use and pollution and for freshwater ecosystems climate change, pollution and water stress (Figure 16).

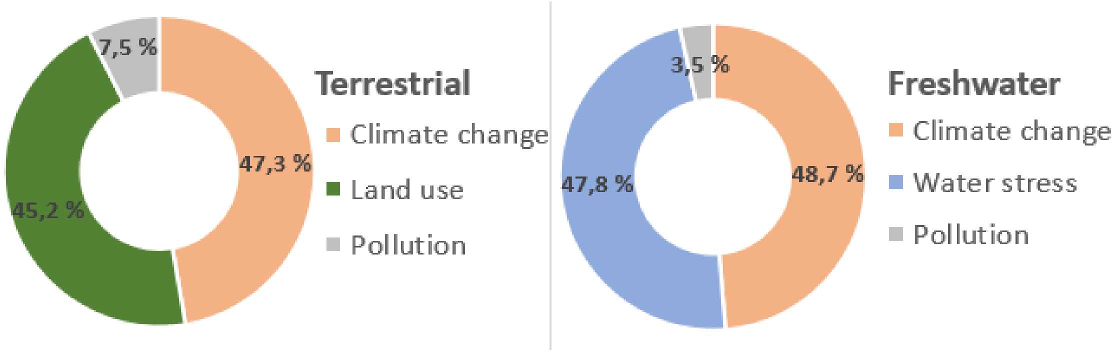

Figure 16. Drivers of biodiversity loss on terrestrial and freshwater ecosystems. Climate change is the most impactful on both ecosystems. Land use change on terrestrial ecosystems and pollution on freshwater ecosystems are almost as impactful as climate change.

The total biodiversity footprint from calculations based on data of physical consumption was 36.66 nBDe. Most of this came from district heating 27.64 nBDe and electricity 8.76 nBDe and a small share from water 0.15 nBDe and 0.11 nBDe from fuels (Figure 17).

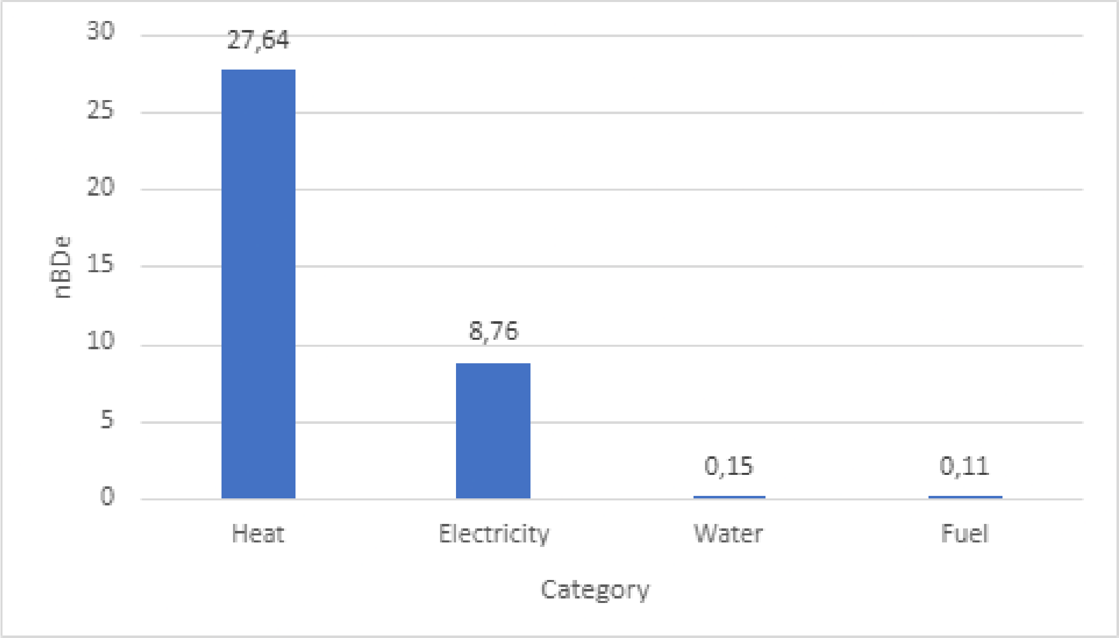

Figure 17. Biodiversity footprint results of physical consumption data.

The energy can also be interpreted with the share of biodiversity footprint to the share MWh consumed. Different energy sources contribute to the biodiversity footprint very unequally compared to the share of energy produced. Most significant contributor to the district heat biodiversity footprint were wood-based fuels (Figure 18).

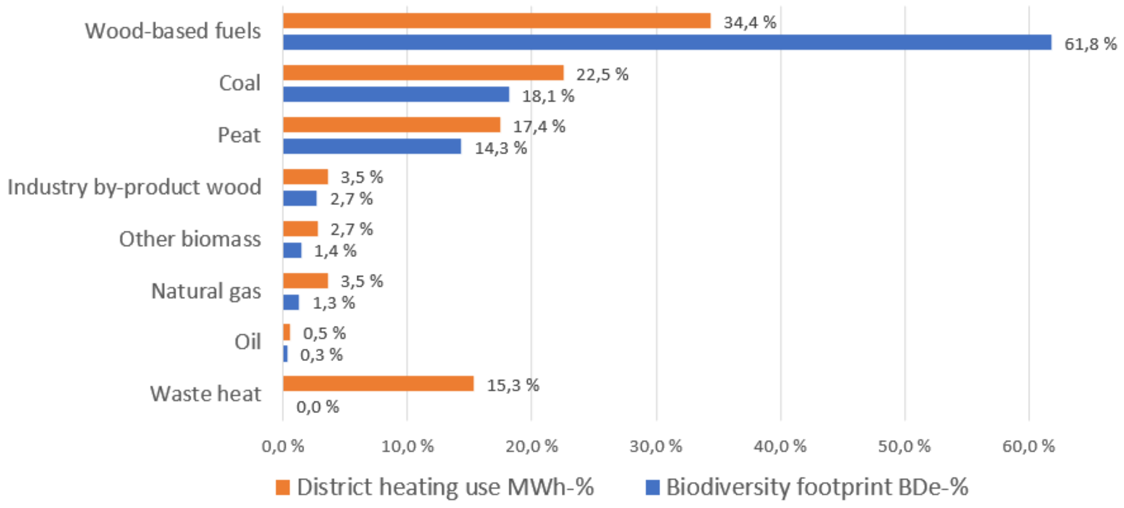

Figure 18. Share of biodiversity footprint and MWh consumed of district heat. This figure contains both district heating energy spectrums.

In the case of electricity, wood-based fuels contributed significantly more to the biodiversity footprint than wind and hydro (Figure 19).

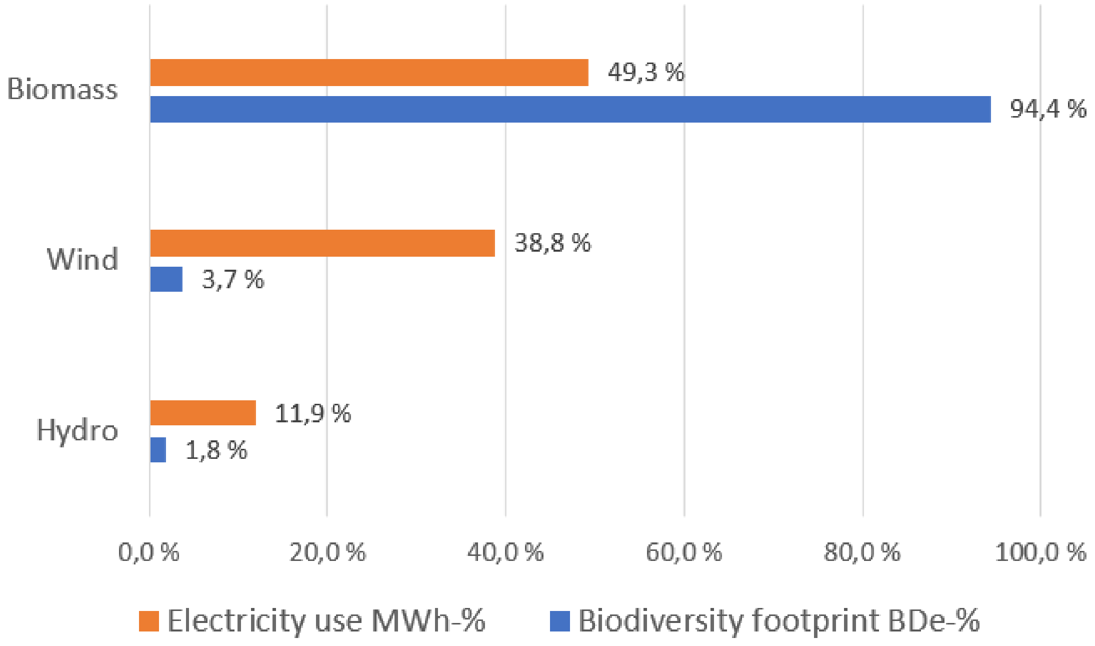

Figure 19. Share of different electricity sources biodiversity footprint and their share on electricity spectrum.

6.2 Global geographic distribution of biodiversity footprint

Geographical distribution of impacts can be investigated in terms of land use, pollution, and water use. The calculation is based on international trade data contained in the EXIOBASE database, reflecting the origin of various product categories' environmental impacts from the perspective of average Finnish consumption (Stadler et al., 2018). The Pymrio were utilized to determine the distribution of the biodiversity impacts (Stadler 2021). Here, we go through notable results based on the maps. Additional and further information about the results on geographical distribution results can be seen in Appendix 3.

Global land use biodiversity footprint of VTT in Finland is 2,4% and resulting in 9th place in global listing. This means that 97,6% of VTT's land use caused biodiversity footprint are located elsewhere than Finland. Biggest land use biodiversity footprints are in small island nations, like Guam 5,7%, Sao Tome and Principe 5,2% and Northern Mariana Island 4,9% (Figure 20).

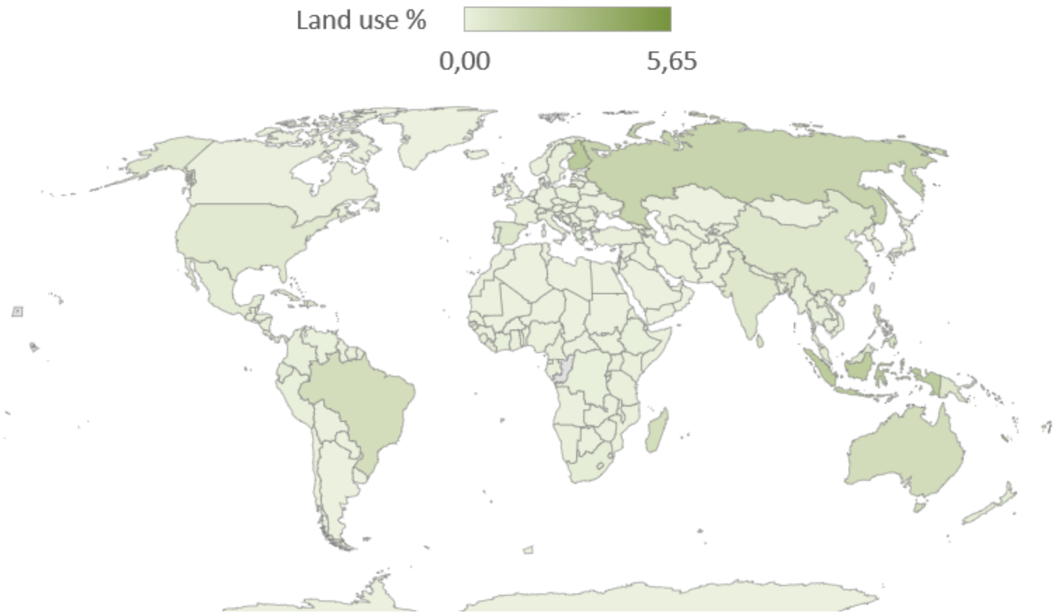

Figure 20. Map of global land use biodiversity footprints. Global land use is particularly harmful in small island states, which are also highlighted in VTT's results. The top ten results were Guam 5,7%, Sao Tome and Principe 5,2%, Northern Mariana Island 4,9%, Seychelles 4,6%, New Caledonia 4,0%, Comoros 3,4%, Mayotte 3,4%, Pitcairn 2,6%, Finland 2,4% and French Polynesia 2,4%. More information on Appendix C.

Biodiversity footprint caused by terrestrial pollution is concentrated in certain countries. The largest share of biodiversity footprint by terrestrial pollution occurs in the United Arab Emirates with 19,2% (Figure 21).

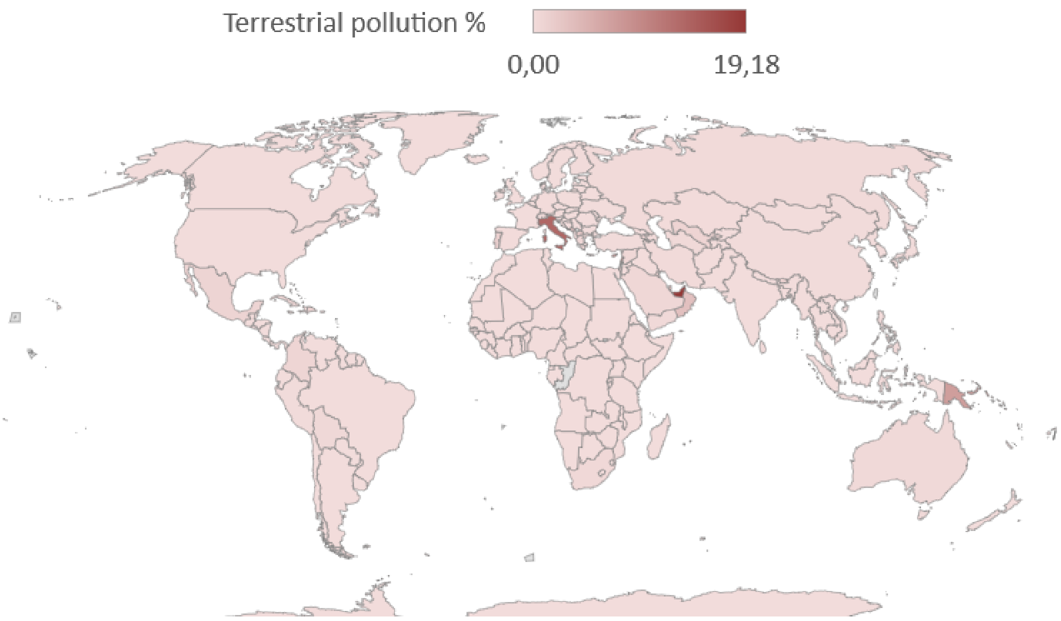

Figure 21. Global distribution of terrestrial pollution in percentages. Ten most significant countries are United Arab Emirates 19,2%, Italy 13,6%, Palestinian Territory 13,0%, Lebanon 9,9%, Cyprus 7,9%, Papua New Guinea 7,2%, Qatar 3,9%, Montenegro 3,2%, Oman 3,2%, and North Macedonia 2,2%.

In terms of water use, by far the greatest biodiversity footprint is in the United States, where the biodiversity footprint caused by water use accounts for 58,8% of the global biodiversity footprint. This is followed by Australia with 14,6%, Jordan with 4,7% and the Bahamas with 3,7% (Figure 22). The top ten countries already show large differences in significance between each other. Countries outside top ten account for well under 1% of global water use caused biodiversity footprint.

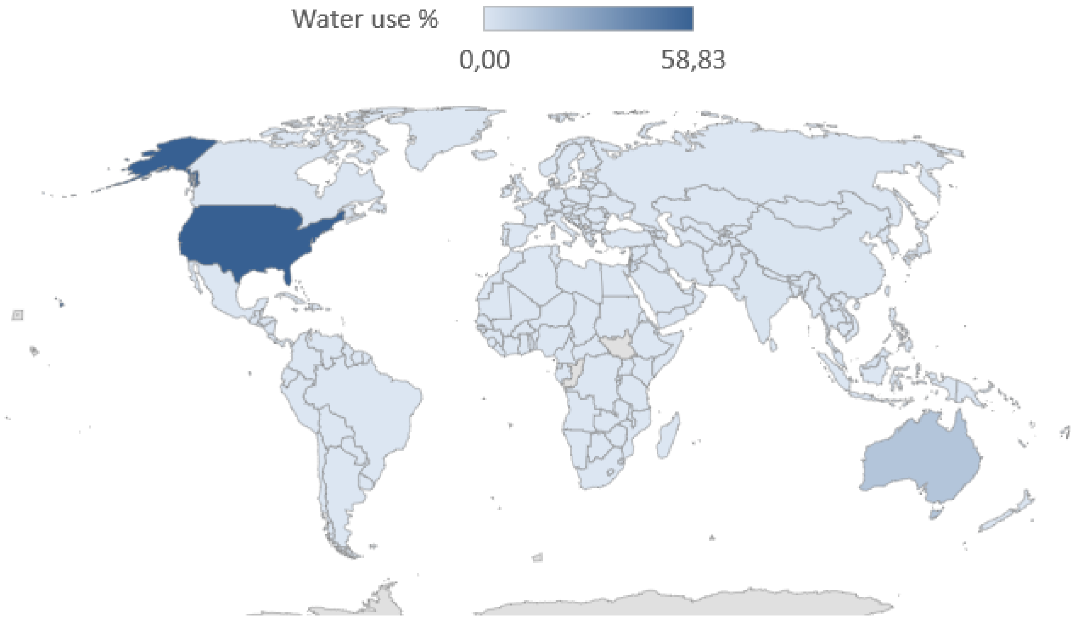

Figure 22. Global distribution of water usage pressure in percentages. The top ten countries in terms of water use are United States 58,8%, Australia 14,6%, Jordan 4,7%, Bahamas 3,7%, Taiwan 1,9%, Malaysia 1,5%, Puerto Rico 1,1%, India 1%, Yemen 0,8%, and Lebanon 0,8%.

Freshwater pollution biodiversity footprint is distributed across the globe. Most significant countries are India 17,8%, China 7,2%, Brazil 6,2% followed by Finland with 4,2% (Figure 23).

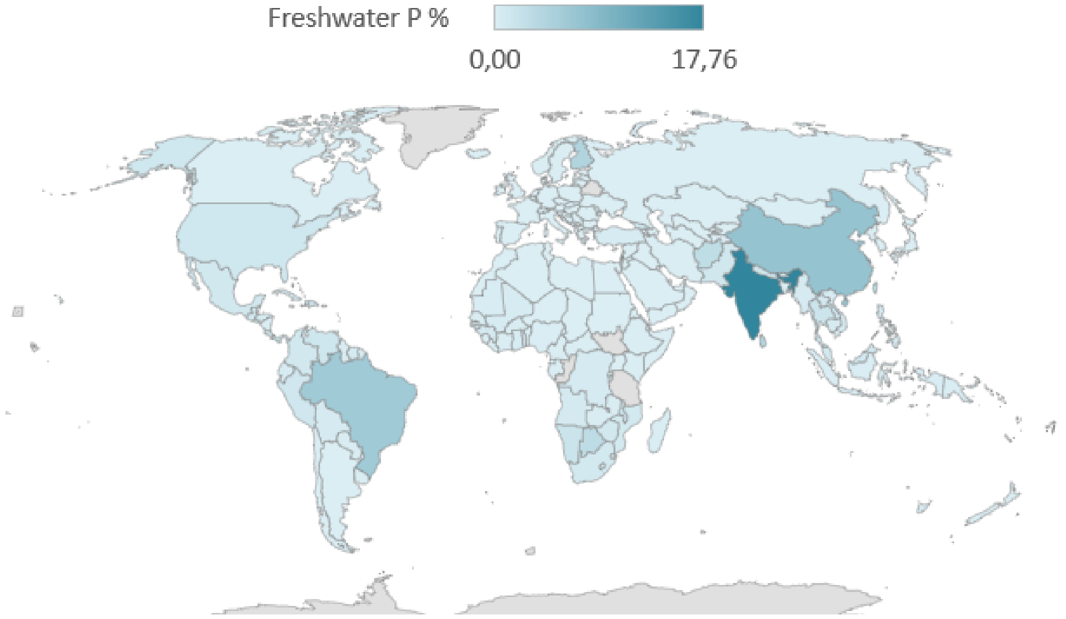

Figure 23. Global distribution of freshwater phosphorus (P) pollution in percentages. Ten most significant countries are India 17,8%, China 7,2%, Brazil 6,2%, Finland 4,3%, Sri Lanka 4,1%, Botswana 3,0%, Afghanistan 2,9%, Panama 2,1%, Namibia 1,7%, and Thailand 1,6%.

The global distribution of biodiversity footprint caused by marine nitrogen eutrophication is very uneven. The most significant country is Estonia, which, very likely due to incorrect data in the LC-Impact, accounts for 79% of the global marine nitrogen pollution caused biodiversity footprint (Figure 24). Most significant countries after Estonia are China 11,9% and Germany 4,2%.

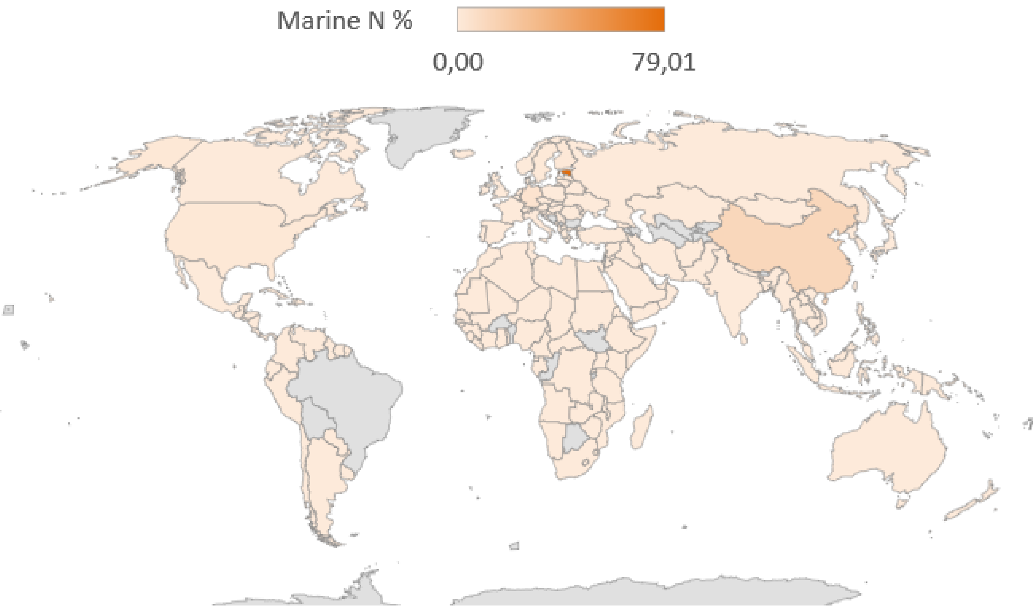

Figure 24. Global distribution of marine nitrogen (N) eutrophication caused biodiversity footprint in percentages. Ten biggest countries are Estonia 79,01% *, China 11,9%, Germany 4,2%, United States 1,4%, Finland 1,2%, Netherlands 1,0%, Sweden 0,9%, Lithuania 0,1%, Latvia 0,1%, and Belarus 0,03%.

6.3 Applicability of JYU method to SBTN framework

The JYU method is suitable for the SBTN framework, mainly Step 1 and to some extent Step 2. The JYU method is, in SBTN terms, a flexible approach to materiality screening and Step 1, for which there are certain requirements. JYU's method meets the SBTN requirements for tool reliability and suitability (Table 1). JYU method meets the set requirements for overarching data quality, pressure estimation data & tools and state of nature data & tools. Each of these criteria has eight different characteristics which JYU method also meets.

Table 1. Criteria and characteristics by SBTN and how JYU method meets these.

Criteria Characteristics	**Overarching Data Quality**	**Pressure estimation data / tools**	**State of nature data / tools**
Relevance	Answers relevant questions.	Covers all the pressure categories on Step 1.	Covers one or more appropriate state of nature metrics.

			Includes pressure-sensitive state of nature and biodiversity data.
Representative	Principles and context within the SBTN methods are aligned.	Pressure data is associated with specific unit processes/activities	Analysis, tool and metrics are compatible with the aims of quantification.
Spatial and Temporal resolution	Spatial and temporal resolution of data are appropriate.	Data on pressures have appropriate spatial resolution for at least Step 1. Information within the tool is based on impacts of activities estimated from present to the recent past.	Sufficiently fine spatial resolution to represent the current state of nature for each pressure and value chain component. Captures nominal present conditions with appropriate level.
Resource Stability and Preservation	Datasets last minimum of 5 years after publication.	Data can be referenced with appropriate versioning and accessed for the duration of the five-year assessment period.	Data can be referenced with appropriate versioning and accessed for the duration of the five-year assessment period.
Accessibility	Data is accessible online. EXIOBASE and LC-Impact are free to use, EcoInvent isn't free, but provides data that is well fitted for the purpose.	Data is accessible online. EXIOBASE and LC-Impact are free to use, EcoInvent isn't free, but provides data that is well fitted for the purpose.	Data is accessible online. EXIOBASE and LC-Impact are free to use, EcoInvent isn't free, but provides data that is well fitted for the purpose.
Interpretability	Data/tools are interpretable with sufficient guidance.	Guidance on how to use the tool will be available.	Guidance on how to use the tool will be available.
Coverage	Data/tools are easily scalable across major subsets of portfolios and organizations.	Data has global extent to facilitate analysis across companies' value-chain.	Data has global extent to facilitate analysis across companies' value-chain.
Authoritative and Accurate	Data are recognized as authorities and accurate	Reflects best-available science and subject to appropriate review.	Reflects best-available science and subject to appropriate review.

SBTN and JYU use the same technical starting points in their methods. Most important of these are the same pressure categories set by IPBES, scope for the assessment, data suitability, coverage, state of nature (SoN) indicators, definition of materiality and disclosure (Table 2).

Table 2 Table of technical starting points and properties between JYU method and SBTN framework.

Method	**JYU**	**SBTN**	**Notes**
Scope	Cradle-to-gate	Cradle-to-gate	Upstream and direct operations
Pressure	IPBES, 8 pressure categories.	IPBES, 8 pressures must be addressed on step 1a materiality screening and 5 on step 1b value chain assessment.	8 pressure categories: terrestrial ecosystem use, freshwater ecosystem use*, marine ecosystem use*, water use, other resource use*, climate change, soil pollution, and freshwater pollution. (*excluded on value chain assessment)
Data	Accounting data, spend of the company, volume of usage (€, kWh, km, kg)	Observational data, estimations using quantitative modelling approaches, which take as inputs specific data for relevant locations and sites. Estimations using data on the activity, spend of the company, quantity of goods or services produced, and geographic location.	JYU method is applicable through estimations on activity, spend and quantity of services produced and used by the company on geographic location. Observational data must be used if possible.
Coverage	Whole yearly accounts and spend of the organisation	Direct operations: 100 % sites and facilities Upstream: All high-impact commodities, at least 67 % of the company's material spend or volume	JYU method fulfils coverage requirements of the SBTN, as it considers 100% of company's direct operations and upstream.
State of nature indicators	Considers pressure-sensitive state of nature and biodiversity of the nature. Result is in biodiversity	Pressure-sensitive state of nature and biodiversity metrics combined to get information on biodiversity on specific locations. Potential metrics are: Species endemism, Species extinction	JYU's method doesn't handle pressure-sensitive state of nature and biodiversity of the nature separately. Both are built in the

	equivalent BDe, telling potentially disappeared fraction of species globally.	risk, Ecosystem integrity/condition, Ecosystem connectivity, Nature's contributions to people, and Delineated areas of importance for biodiversity.	method from different databases and result tells global species extinction risk on BDe metric.
Definition of materiality	Environmental materiality	Environmental and social materiality	
Disclosure on business depencies and impacts on nature	Impacts only	Impacts only	Decencies may be covered in the future on the SBTN

7 DISCUSSION

In this section we discuss the results of the biodiversity footprint measurement project, suggestions for improvement and limitations. We also discuss the suitability of the JYU methodology for the Science Based Targets for Nature -framework and what limitations apply here as well.

7.1 Biodiversity footprint

VTT's total biodiversity footprint came to 105.73 nBDe. The largest part of this was the acquisitions, with procurement, services, and investments accounting for about 65% of the total footprint. The remainder was mainly covered by district heating, accounting for about 26% of the total footprint, and electricity, accounting for about 8% of the total footprint. While the acquisitions make the biggest share, energy use shows up to be greatest contributor to biodiversity loss. Heating itself is by far the biggest single category of biodiversity footprint and electricity is a great contributor as well. It should be noted that energy use was calculated based on physical consumption compared to acquisitions monetary-based calculations and used different databases for impact factors, which can alter the results comparability to the acquisitions.

Comparing results with previous studies is not as straightforward, since similar studies are still limited, and assessments have been done for organizations that differ from VTT's operations. On the other hand, all the studies utilize same databases and have assessed Finnish organizations (El Geneidy et al., 2023; Peura et al., 2023; Pokkinen et al., 2023; Pokkinen et al., 2024; Pykäläinen et al. 2024). Most similar study is the one done for University of Jyväskylä since it and VTT are both research organizations. University of Jyväskylä's biodiversity footprints biggest impact categories included IT supplies, machinery and supplies and energy (El Geneidy et al., 2023), and similar categories are highlighted also in this study. Energy, most notably heating but also electricity uses also rise to be top categories in previous studies. Most of these studies use monetary values for energy (El Geneidy et al., 2023; Pokkinen et al., 2023; Pykäläinen et al. 2024), but in the case of city of Tampere physical consumption was used in which heating made 13 % of the total biodiversity footprint and electricity 9 % of the footprint (Pokkinen et al., 2024). Results are similar, considering the organizational differences.

Since there are few assessments done with the utilized JYU method, table 3 gathers information from previous organizational studies. These include their biodiversity footprints (nBDe) and top categories associated with the footprint. Additionally, there is comparison with two key figures describing the scope of organizations operations, revenue (€) and number of employees (worker). These are proportioned with biodiversity footprint of the organization from given year. The small number of examples do not offer great evaluation on what these proportions tell, but if the method is used more in the future, these can serve as a good starting point and be, for example, key figures utilized in biodiversity accounting.

Table 3. Comparison of the organizational studies made with JYU method. Here "*" marks the reference used for revenue (€) and "**" both revenue and the number of workers. JYU study itself included this information and City of Tampere had specific exclusions of some operations within that study, so nBDe/worker is taken from that study. For nBDe/€ in Tampere study, same operational revenues were also excluded to make this table.

Study	**nBDe**	**Top categories**	**nBDe / €**	**nBDe / worker**
VTT (VTT, 2023a*)	105,73	Heating, Other business services, Machinery and equipment, electricity	6.4e-7	0,05
JYU (El Geneidy et al., 2023)	36,6	IT supplies, Machinery and supplies, Energy, R&D services	1.7e-7	0,01
City of Tampere (Pokkinen et al., 2024; Tampere 2022*)	557	Food products, heating, construction, electricity	15.7e-7	0,07
S-Group (Peura et al. 2023; SOK, 2021**)	33 202	Food products, fuels, utility goods, services and purchases	43.6e-7	0,9

Previous studies also highlight that the role of climate change as significant driver for biodiversity loss driver (El Geneidy et al., 2023; Peura et al., 2023; Pokkinen et al., 2023; Pokkinen et al., 2024; Pykäläinen et al. 2024), which is the case for this study as well. This further highlights the notion that limiting climate change and halting biodiversity loss are mutually supportive goals and must be addressed simultaneously (Pörtner et al., 2021).

The comparison of the biodiversity footprint assessments of VTT and University of Oxford is interesting, as both organizations are focused on research and the results highlighted many of the same activities. The methodology used by University of Oxford is also similar to ours. The University of Oxford's biodiversity footprint is largely not under their direct control and the five most impactful activities were the supply chain for research activities, the supply chain for day-to-day running of buildings, food consumption, electricity consumption and the supply chain for construction (Bull et al., 2022). The main impacts associated with Oxford's research activities were chemicals and various consumption products, such as plastics, and the day-to-day running of buildings included activities such as IT equipment and paper products. These activities were also highlighted in the VTT results, as the top ten EXIOBASE-categories included "Furniture; and other manufactured goods n.e.c", "Computer and related services", "Research and related services", "Chemicals nec", and "Office machinery and computers". Electricity consumption was also highlighted in both biodiversity footprint assessments. The University of Oxford also has direct impacts, such as on construction and land use, which were reflected in the results. University of Oxford has around 1000 hectares of land under its control (Bull et al., 2022). However, in comparison, these impacts are significantly smaller than the upstream impacts. For example, the biodiversity impacts of the University of Oxford's lab equipment supplies were significantly greater than the impacts of international flights, electricity consumption and building materials combined (Bull et al., 2022). This suggests that the biodiversity impacts of research organizations are strongly focused on the day-to-day activities of the organization (energy consumption and basic infrastructure, such as IT related) and upstream activities, with a particular emphasis on research equipment and chemicals.

Upstream impacts relate to one key discussion point in University of Oxford's study, that most of the impacts are not under direct control of the organization (Bull et al., 2022). This can be said to be true in our case and other studies conducted with the same method (El Geneidy et al., 2023; Peura et al., 2023; Pokkinen et al., 2024; Pykäläinen et al. 2024). For example district heating, hence biodiversity footprint of it can be affected only by contract with the service providers and options in Finland are tied to location and are usually limited. This is reflected in this study with top EXIOBASE categories, which are purchases that VTT as only indirect control over.

Global distribution of VTT's biodiversity footprint is mostly located outside Finland. This follows the trend shown in other studies as well, that majority of biodiversity footprint and with that, the caused harm on biodiversity spreads elsewhere (El Geneidy et al., 2023; Peura et al., 2023; Pokkinen et al., 2024; Pykäläinen et al. 2024). Finland's biodiversity footprint in percentages from all countries was for land use ranked 9th with 2.4%, for freshwater P pollution 4th with 4,3% and for marine N pollution 5th with 1.2%. Terrestrial pollution and freshwater use's share for Finland was well under 1%. These results are based on global trade routes data from the EXIOBASE database (Stadler et al., 2021). This means that the geographical impact of the specific products used by VTT cannot be estimated, but this gives an average result for products in the same procurement category consumed in Finland. In any case, this indicates that VTT's biodiversity footprint is mainly abroad, which is to be expected from an organization like theirs. For example, VTT doesn’t directly use significant amounts of natural resources produced in Finland, whose biodiversity impacts would therefore be concentrated within Finland's borders.

Compared to other biodiversity footprint assessment methods, the method developed by researchers from the University of Jyväskylä has many advantages. The method is easily scalable to large and multi-sectoral organizations, which makes it very flexible to use. This method takes into account all ecosystem types, as many others only consider terrestrial and freshwater, like BFM and CBF methods presented earlier in the theoretical background. Considering all ecosystem types, including marine, allows the use of the BDe indicator, which has the advantage of comparability of results and outlining global biodiversity loss. The BDe indicator expresses potential extinctions of species, which we find easier to understand than mean species abundance. Mean species abundance can be applied to both terrestrial and freshwater ecosystems and to all drivers of biodiversity loss, so these results can be summed together. However, this is harder to comprehend. For example, biodiversity impact MSA/ha for freshwater is difficult, because aquatic environments (running water) are three-dimensional compared to terrestrial (land surface) two-dimensional environments. In order to use the CBF and BFM methods, some basic GLOBIO and ecology skills are needed to make the correct decisions what type and intensity of land use should be used for the calculations. JYU method also is relatively easy to use, since calculations can be done using Excel, without LCA software. Impact factors utilized in this study are planned to be open access in the near future (El Geneidy et al., 2023), making the method easily accessible.

However, the biodiversity footprint metric developed by the researchers of University of Jyväskylä also has improvement possibilities. Currently, the metric does not take into account direct on-site biodiversity impacts (such as construction work’s direct land use), but this was not a major issue in the VTT project. Also, data on the actual supply chains of the procurements haven’t been used, so the results are indicative for each acquisition category. However, it should be noted that biodiversity as a concept is very complex and multi-level. It is difficult to capture all levels of biodiversity loss under a single indicator. For example, genetic composition and ecosystem function variables are not really considered in any LCA methods (Damiani et al., 2023). Also, for example, invasive alien species are known to be one of the major drivers of biodiversity loss but have not been included in LCA methods. These elements are also not considered in the method used in this study (El Geneidy et al., 2023). Biodiversity footprint methods are therefore indicative at best and measurable data is not available for all variables.

7.2 Possibilities to mitigate biodiversity footprint

A mitigation hierarchy can be used to reduce the biodiversity footprint, as recommended by the SBTN in Figure 10 and Moilanen & Kotiaho (2021) propose in their similar framework of alternative mitigation hierarchy. The main starting point for mitigating the biodiversity footprint is to avoid impacts. To avoid impacts, best way is to reduce consumption, which is often not possible. Avoiding impacts, i.e. business activities, altogether is challenging as business of the organizations can't be cancelled completely. Direct impacts are perhaps easier to avoid than upstream, such as avoiding the construction of a road in an ecologically significant location. In the case of upstream, impacts can be minimized by using products and services that are better options for biodiversity. The biodiversity footprint results of VTT highlighted many physical assets, such as "Furniture; and other manufactured goods n.e.c" and "Machinery and equipment n.e.c" from the EXIOBASE categories, for which it could be considered whether all purchases are necessary or whether better alternatives could be preferred. Chemicals, for example, are also products that are necessary for the research, but it is likely to be possible to minimize the impact by investigating the origin of the products. The biodiversity impact of procurement can be minimized by looking at where products are sourced from. Impacts can be minimized by avoiding countries with particularly rich biodiversity.

In VTT's results, biodiversity-intensive categories can be examined by comparing the ratio of acquisition volume to biodiversity impact or by using a fourfold field, which provides the same results, but also presents the median of acquisition volume and biodiversity impact intensity. The most biodiversity intensive categories and those with high volumes are potential targets to focus on to reduce the biodiversity footprint. Among the EXIOBASE categories, these are in particular "Chemicals n.e.c" and "Furniture; other manufactured goods n.e.c" Activities with a low volume but a high intensity of biodiversity impact are also potential targets. In the results, the most significant biodiversity impacts arise from acquisitions with a high volume. The largest impacts are caused by "Other business services" (approximately 20 % of monetary value) and "Machinery and equipment n.e.c" (approximately 15 % of monetary value), which have a biodiversity footprint intensity close to the median but a very high volume. For these acquisitions, and all the other top ten most harmful EXIOBASE categories, it can be examined whether it would be possible to find services and products for which impacts could be avoided or minimized.

District heat was the single largest contributor to the biodiversity footprint, and electricity also made a significant contribution. For energy, the same intensity-volume relationship can be examined. In the district heating energy spectrum, wood-based fuels were clearly the most harmful in terms of intensity, but this is difficult to mitigate as this energy source is an important part of the district heating network and is already used in the "green district heating" contract. However, it is important to note that the biodiversity footprint intensity of wood-based fuels is higher than, for example, coal, but the carbon footprint is lower for bio-based fuels. In the case of electricity, bio-based fuels accounted for almost all the biodiversity impact of the electricity spectrum. Electricity produced from biomass could be replaced in the electricity spectrum by increased shares of renewables, such as wind or hydropower, or by nuclear electricity. In order to minimize energy consumption, it could also be considered whether there is room for improvement in the energy efficiency of equipment or buildings. The high contribution of biofuels and wood-based fuels to biodiversity impacts suggests that they can be used at this stage of the sustainability transition to tackle climate change issues, but as a long-term solution they cause significant impacts on biodiversity.

Following the no net loss and net positive impact mitigation hierarchy, Moilanen & Kotiaho (2021) put off-setting as the third option and restoring degraded nature on site as the last option, while in the traditional version, also highlighted by SBTN, off-setting is the last option. Off-setting is a more efficient and quicker way to reduce the biodiversity footprint of organizations than restoring degraded nature. This is because often off-setting rights can be purchased from a habitat bank and are already allocated to natural land, while rehabilitation of degraded land takes up to decades. The success of degraded land rehabilitation is also associated with uncertainties related to concerns about feasibility, reliable implementation, and verification and durability of restoration during and after the project. We believe that off-setting is also a more feasible option in the case of VTT, as VTT does not have many activities directly related to land and sea use.

7.3 Organizational improvement possibilities

One of the benefits of the utilized method is that it can connect financial account data to environmental accounting (El Geneidy et al., 2023). In this case this could be beneficial. Calculations were made based on account categories and what was included in them. This is fairly accurate, but results could be improved with linking every individual acquisition with the most suitable EXIOBASE category. Doing this afterwards for a whole year is time-consuming, but since acquisitions are also otherwise needed to be categorized while making them, linking the acquisition with the impact factors already when making one would create efficiency to assessment. This would make reposting and disclosing impacts on biodiversity relatively effortless and lead to more accurate results, giving good starting point for biodiversity accounting.

One of the challenges calculations faced was related to how acquisitions were categorized within organization. Account categories were not always straightforward and included different types of acquisition that seemed inconvenient and sometimes needed extra work to search what they included. In some cases, categories that were labeled under services-type still included acquisitions that would otherwise be goods. These inconveniences might be acceptable within accounting acquisitions, but in the grander scheme, with assessing environmental impacts becoming important part of organizational accounting and these types of data important sources to evaluate the impacts, we see that development of acquisition categorization to be more precise and aim for better accuracy would be useful in the future. As we suggested connecting current categories with EXIOBASE categories, this also could be done in reverse, meaning that revamping the whole acquisition categorizations to be dominated by EXIOBASE-categories. This could be even more efficient in terms of assessing the impacts, but reconstruction of current system might not be as a feasible option.

7.4 JYU method application to SBTN

We looked at the SBTN framework and the application of the JYU methodology to it. We reviewed the sources provided by the SBTN and drew the best possible conclusion as to how the JYU methodology can and cannot be applied. Our conclusion is that in many respects the JYU methodology is well suited, particularly for Step 1 materiality screening and value chain assessment. This part of the SBTN steps is also assumed to be the most laborious. The JYU method is also helpful for Step 2 Interpret & prioritize based on the results already obtained from Step 1. However, this section already starts to look at the results from the biodiversity loss pressure level point of view and more detailed information of spatial resolution is needed.

Compared to other nature-related assessment and disclosure approaches, the SBTN is probably the most focused on biodiversity. The SBTN also places a very strong emphasis on a science-based approach that seeks to maximize the positive impact on biodiversity. In terms of impacts, all standards are similar and oblige disclose on pretty much the same issues related to biodiversity. However, it should be noted that the SBTN only takes biodiversity impacts into account, compared to other approaches discussed in the theoretical background. The ESRS standard will become a regulatory standard as part of the CSRD and will require more comprehensive disclosure on topics such as risks, opportunities and depencies related to biodiversity and how these relate to the organization's strategy and operations. The GRI and TNFD standards are aligned with the ESRS, as synthesized by Lammerant et al. (2023). We concluded that the SBTN is certainly a useful and more narrowly focused framework that will also be helpful for the ESRS, but the GRI and TNFD standards are more comprehensive and more aligned with the ESRS.

7.4.1 Data and tool applicability

The JYU method seems to be suitable for the data and tool requirements set by the SBTN. Data and tool requirements apply to Step 1b, the value chain assessment. These requirements may still change as the SBTN evolves. According to the information currently available, the JYU methodology meets the data & tool requirements. Some of the requirements are fairly general level of application of the scientific method, for example concerning the reliability, transparency and application of the data and tool. For more specific details, the method also meets the requirements. More specific details on the data include its availability, coverage in different sectors and accuracy. The data & tool should also be widely applicable. This means that it could be used for large-scale analyses across major subsets of portfolios, for example for corporation-level footprints. The JYU methodology is highly scalable and suitable for mapping biodiversity footprints of a wide range of organizations. The data must be representative, which means that the information from the data must relate first and foremost to defined pressures and which activities in the organization are causing them. The JYU methodology uses the same drivers of biodiversity loss as defined by IPBES, so the data can also interpret to be representative. For the State of Nature, the data must be appropriate from a geographical, ecological, and social perspective. For the data, other requirements are that they must be available online, preferably free of charge, they must be identified as authoritative and accurate, and the datasets must be available long-term and persistent. The data used in the JYU methodology is mostly available free of charge, as the EXIOBASE and LC-Impact databases are free of charge. EcoInvent is paid, but SBTN also allows the use of paid databases if they are well suited for the purpose.

The JYU methodology is also in line with the SBTN in other technical aspects. The most important of these is the IPBES key drivers of biodiversity loss. This is the most important similarity, because as a result SBTN and JYU use the same scientific background knowledge, which underlies the biodiversity loss. The 8 drivers of the biodiversity loss are the same, which is the main theoretical knowledge behind the use of the method and on which the rest is built. There are other important similarities. Both use the same scope, cradle-to-gate, so downstream nature damage is not considered in either. Scope similarity is an important technical starting point that must always be taken into account when starting any kind of LCA calculation. SBTN also considers, at least for the moment, the environmental impacts. It does not consider environmental dependencies, risks or opportunities, as neither does the JYU method.

7.4.2 Pressure estimation by modelling

SBTN allows for pressure estimation in Step 1 by modelling. This allows the JYU method to be easily scalable to cover the whole organization. Organizations don't always have primary data for all their direct and upstream operation, datasets often being necessary. According to SBTN, estimations can be generated using data on the activity, spend of the company, quantity of goods or services provided, and geographic location. SBTN requires at least 67% coverage of upstream and 100% of material direct operations in Step 1, which is quite a large amount of work. JYU's method is very suitable for Step 1 because it's based on financial accounts of the organization. JYU's method takes into account 100 % of all the spend of the company and is therefore easily scalable to any organization.

The SBTN uses two different state of nature indicators. The JYU methodology differs somewhat from the SBTN framework in this respect. The SBTN looks at the effects of biodiversity loss drivers through pressure-sensitive state of nature and biodiversity state of nature. Pressure-sensitive state of nature indicators are intended to summarize the features of the state of nature most directly connected to the pressure being assessed. Biodiversity state of nature indicators are intended to inform about the state of biodiversity. The JYU methodology does not consider the two separately. In practice, the pressure-sensitive state of nature indicators is also taken into account in the JYU method, as they contribute to the underlying potentially disappeared fraction of the species. However, it cannot be completely certain whether the state of nature indicators need to be treated separately.

Like said on the method section, Step 2 requires each pressure to be considered separately from the others. This means, for example, looking at land use, water use or pollution separately. In the JYU method this means that the main result used on Step 2 would be mid-point results of the method, each pressures environmental impact results. Also, this section requires sub-national spatial resolution on direct operations. This considers all direct operation activities that are defined as being material in Step 1. This is where the JYU method is really challenged for the first time. For direct operations, one would have to identify environmental pressures at the sub-national level that are not directly available from this method. For upstream activities, the JYU method is still useful, since for these activities the spatial resolution is still sufficient at this stage to provide country-specific accuracy. However, these data also need to be considered at the level of environmental pressures and not in biodiversity metric, BDe, that JYU method uses.

For Step 3 JYU method isn't applicable, at least without some modifications. It's already clear that country level spatial resolution isn't enough for this step even for the upstream processes. The goal of this is to set targets for best possible reference point. In practice this mean's best possible information on source of the upstream activity meaning production unit level or other subnational level of accuracy. Other subnational level can for example be where in the country activity takes place, regional or sourcing area level. For direct operations already on Step 2 country level data isn't sufficient and consequently not in Step 3.

Step 4 Act is the implementation of the targets set in the previous step, following the mitigation hierarchy, which can be implemented, as we already discussed in the previous chapter on biodiversity footprint reduction. However, if the SBTN framework is to be followed, the implementation of Step 4 targets will be based on the targets of Step 3. Step 4 cannot therefore be based on the results of the biodiversity footprint developed by researchers at the University of Jyväskylä. Step 5 Measure, report & verify will contain instructions on how to disclose the SBTN process, so this Step does not directly relate to the biodiversity footprint methodology developed by the University of Jyväskylä researchers.

7.5 Limitations

The main limitations in calculating the biodiversity footprint came from the data and its accuracy. The financial account data we received contained many accounts with products or services of different EXIOBASE categories. We had to either generalize the content of one account to one EXIOBASE category or roughly allocate the account content to more than one EXIOBASE category. This introduces some uncertainty into the results, but we believe that the overall impact is marginal.

We also had to remove some categories, the main one being facility rentals within the facility portfolio category. These rents possibly included energy and water consumption, which we calculated separately. The rents were also significant in monetary value, so this would have introduced a significant error in the calculations and a risk of double counting. This exclusion still might ignore the occupied land that is associated with facility rentals.

For energy billing, we obtained an accurate energy breakdown of electricity consumption, but for district heating we had to make assumptions about its content. We knew that there were two different types of contracts, but we could not get a location-specific distribution of district heat. This causes some error in the district heat calculations, but results are mostly very indicative. Further research could look more specifically into location-specific district heating results and use more spatial method to assess biodiversity footprint (e.g. Vainio et al., forthcoming).

There were also some EXIOBASE categories, which causes uncertainty on the results. One challenge considers the chemicals account, which contained numerous different chemicals that could not be separated to different EXIOBASE categories. This lack of specificity introduces a significant degree of uncertainty regarding the impact of chemicals on biodiversity. Given their widespread use and significance on the results, accurately assessing the biodiversity footprint of chemicals would be beneficial in future research. Similarly, the EXIOBASE categories “Other business services n.e.c” and “Furniture; other produced goods n.e.c”. pose challenges due to the diverse range of services and products they contain. This diversity introduces uncertainties into the results, as it becomes challenging to precisely quantify the biodiversity footprint associated with these categories. However, despite the uncertainty, the data available currently provides the best possible information on their impact and gives valuable information on the decision making. Also, restricted amount of EXIOBASE categories (200) limits potential to improve categorization of impacts. EXIOBASE data on the distribution of biodiversity loss drivers is based on 2011 data, while the quantities of these drivers are based on 2019 data (El Geneidy et al., 2023), so data is relatively old, which will have its effect on the results.

We had to exclude gas gars from the calculations, which slightly affect results. While gas cars were used to some extent because we didn’t have biodiversity footprint factor for them. Although gas cars contribute environmental impacts on some extent, their contribution to the overall biodiversity footprint is likely to be marginal. Consequently, their exclusion does not substantially alter the overall findings of the study based on total biodiversity footprint of fuels being small and the number of gas cars is smaller than diesel and gasoline. However, the footprint of gas cars depends on what type of gas were use (bio or natural gas) and gas cars can usually be driven with gasoline also.

Compared to other studies done with the similar method, this study lacks annual calculations and combined carbon footprint calculations. Some of the previous studies have calculated biodiversity footprints for two to three calendar year, which gives better perspective on the biodiversity footprint (El Geneidy et al., 2023; Pykäläinen et al., 2024). In this study the focus was on biodiversity footprint assessment, although mutual carbon footprint calculations could be done easily, since the method allows inclusion of it with the use of same databases (El Geneidy et al., 2023; Pokkinen et al., 2023; Pokkinen et al., 2024). Carbon footprint is also necessary midway step for biodiversity footprint, as it is included in climate change, one of the drivers for biodiversity loss (El Geneidy et al., 2023). In this study benefits of including carbon footprint would have been slim, since VTT itself has expertise in that field and have conducted assessments for greenhouse gas emissions for the year 2022 (VTT, 2023b). On the other hand, inclusion of carbon footprint calculated with JYU method could have offered interesting comparison between assessment methods.

There are still some limitations to comparing the SBTN framework and the JYU methodology. Foremost among these limitations is the incompleteness of the SBTN framework, particularly evident in the lack of concrete examples and practical applications beyond the initial steps. Although a biodiversity short paper and technical guidance outlines the first two steps of the framework, subsequent steps remain largely unexplored. However, technical guidance documents provide decent insight on the steps where JYU method is or isn't applicable. Technical guidance of the first two steps gives hints about the further steps, where we draw our conclusions about the applicability of JYU method to later steps. Overall, this lack of detailed guidance and examples causes uncertainty with our comparative study.

8 CONCLUSIONS

The main purpose of our study was to assess VTT's biodiversity footprint, what its main drivers are, how it could be reduced and whether organizational improvements could be made in the future to facilitate the study. We identified the overall biodiversity footprint and its most relevant business activities, which were energy and services and products related to the daily activities of the research organization. Most of the impacts were on upstream activities of services and products located outside Finland's borders. In terms of acquisitions, activities with a high biodiversity intensity or with a high volume of acquisitions were the most potential mitigation targets. For energy, the greatest potential for reducing the biodiversity footprint is the reduction of wood-based fuels and biomass in the energy mix. In terms of organizational improvements, we would suggest investing in the quality and accuracy of financial accounting and the possibility of including in the accounting system information on the procurement categories of products in relation to EXIOBASE categories, which would make future assessment easier.

We also investigated the applicability of the biodiversity footprint assessment method developed by researchers of the University of Jyväskylä to the Science Based Targets for Nature framework. According to our results, the biodiversity footprint assessment method developed by researchers of the University of Jyväskylä meets the SBTN requirements for data & tool use in Step 1b, is partially applicable to Step 2 and there are many technical and theoretical similarities between the two frameworks. The study still had limitations related to the biodiversity footprint assessment and the comparison of frameworks, due to the incompleteness of the SBTN framework and the lack of practical examples.

In this study, we obtained a new case study using a biodiversity footprint assessment method developed by researchers at the University of Jyväskylä, which provides valuable insights into the nature of biodiversity impacts in research organizations. This builds into a growing body of studies conducted with the method and hopefully gains more interest to biodiversity footprint assessments for other organizations as well. We also found out that the method developed by the University of Jyväskylä is applicable to the SBTN framework and has several advantages over other methods. VTT's results could be used as a basis for further research on biodiversity-related impacts of specific procurement categories, such as chemicals. The limitations found in this study could also be complemented and refined. The analysis related to the SBTN, and other biodiversity disclosure frameworks should be further explored in the future, once the framework and guidelines are fully developed. This study provided initial information on how to integrate biodiversity footprint assessment methods and fill the gap between nature-related disclosure approaches. In the future, more comprehensive analysis is needed on different assessment methods and disclosure frameworks, as we mainly discussed one method and one framework.

This study assessed the biodiversity footprint by examining the direct drivers of biodiversity loss and evaluating the approximate geographical distribution of this footprint using global databases. This assessment has provided valuable insights into VTT's impact on nature. The proposed solutions for mitigating the biodiversity footprint, and consequently biodiversity loss, are based on these identified direct drivers. Notably, most impacts occur upstream and are under the indirect control of the organization. While reducing consumption appears efficient on paper, the motivation for change can be a slow process. Convincing scientists that certain research endeavors are unnecessary, particularly when research chemicals, materials, and equipment pose a significant risk to biodiversity, is challenging. Determining which business services to eliminate requires careful consideration. Recent studies have emphasized the need for transformative changes that address not only direct but also indirect drivers of biodiversity loss for more effective conservation practices (Coffey et al., 2023; de Koning et al., 2023). For VTT, research can facilitate technological transformative change, potentially providing innovative solutions. Nonetheless, there could be room for improvement through internal governance and values. Future research could explore the biodiversity footprint with emphasis also on indirect drivers and investigate how these can be more effectively integrated into conservation strategies and discussions linked to biodiversity footprints. Such an approach could yield more comprehensive and sustainable outcomes for transformative biodiversity conservation.

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APPENDICES

APPENDIX 1: A acquisitions that were allocated to each EXIOBASE-category

EXIOBASE Category	**What is included**
Air transport services (62)	Air freight purchases for imports
Ceramic goods	Coffee mugs
Chemicals nec	Research chemicals, etaxes, oligos and enzymes and gases
Collected and purified water, distribution services of water (41)	Process water for research
Computer and related services (72)	ICT related expert, planning, maintenance and data security services, fees for software and information databases
Construction work (45)	Facility repairs, research research subcontracting
Education services (80)	Training of personel, participation fees
Electrical machinery and apparatus n.e.c. (31)	Electrical components, products, low-value ITC accessories, devices and equipment
Electricity nec	Electricity for a single office building that is not under the same electricity contract as others
Financial intermediation services, except insurance and pension funding services (65)	Accounting, auditing and collection and credit status services
Food products nec	Coffee, food supplies for research purposes
Furniture; other manufactured goods n.e.c. (36)	Wide variance of materials and goods: furniture, building materials, clean room products, low value non-electrical equipment, maintenance products, office supplies, laboratory products, personel protection, gifts
Glass and glass products	Laboratory glasses
Health and social work services (85)	Occupational healthcare services
Hotel and restaurant services (55)	Coffee machinery services, external and internal meeting costs, meals for personnel, meeting and negotiations costs, staff parties, travel expenses
Insurance and pension funding services, except compulsory social security services (66)	Indemnity, vehicle, liability, personal, property and other insurances
Machinery and equipment n.e.c. (29)	Research machinery and equipment
Medical, precision and optical instruments, watches and clocks (33)	Eyeglasses for workers
Membership organization services n.e.c. (91)	Membership fees

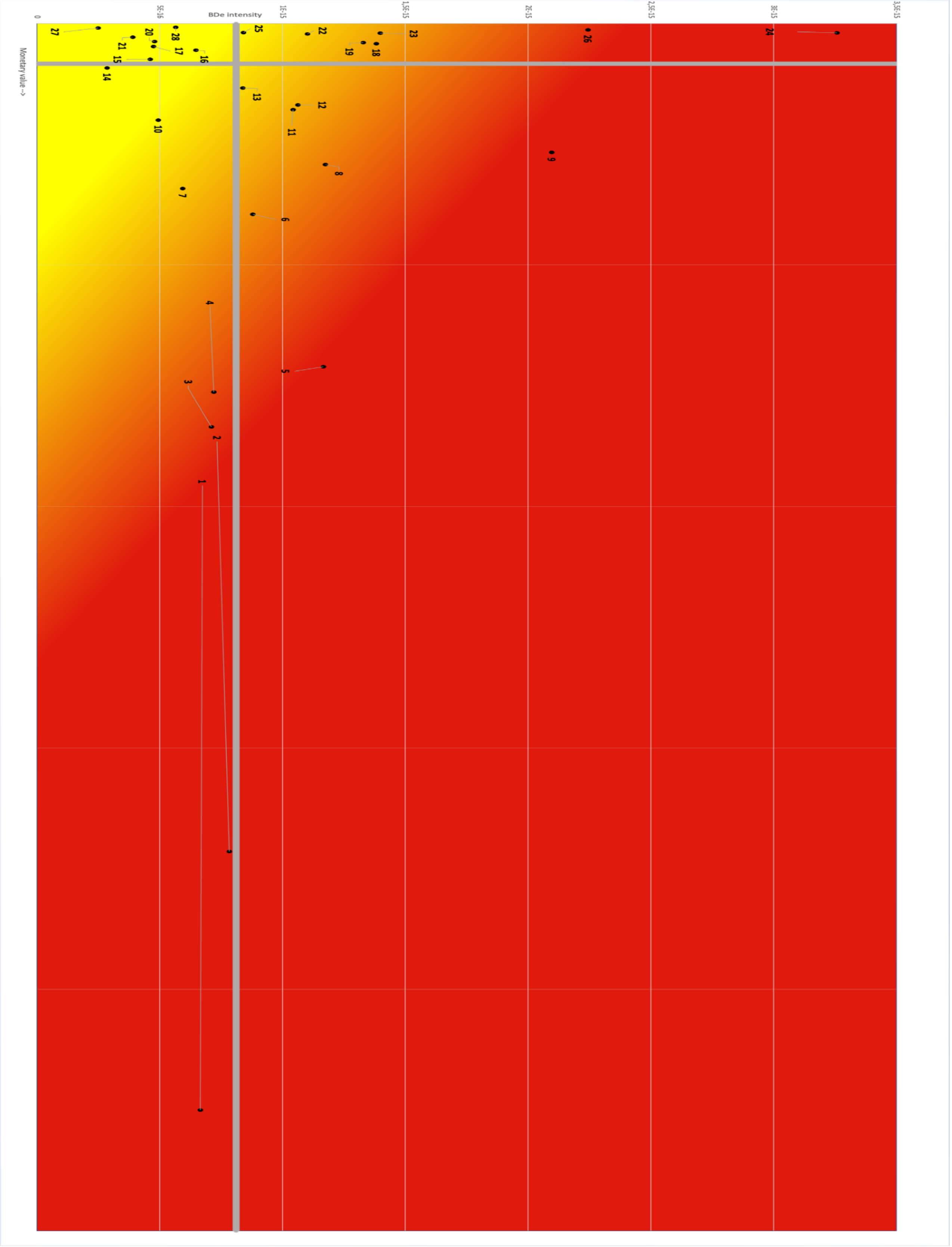
Motor Gasoline	Fuel for vehicles, e.g. forklifts and non-organization owned care
NA	Facility rents, article processing fees, VATs, sponsorships.
Office machinery and computers (30)	Computers and related ICT equipment, parts and accessories.
Oil/hazardous waste for treatment: incineration	Hazardous waste fees
Other business services (74)	Services that don't fall under other business-related service categories. Cleaning, Security, repair and maintanence, marketing, tax consultancy, other administrative, patents, translation, waste management, consulting, legal
Other land transportation services	Freights, courier and traveling costs
Other non-metallic mineral products	Research minerals
Other services (93)	Events, webinars, exhibitions, participation fees, public payments, facility arrangements
Paper and paper products	Paper products
Plastics, basic	Laboratory disposable products, mechanical pipets and tips
Post and telecommunication services (64)	Data transfer, telephone and mailing and courier costs
Printed matter and recorded media (22)	Advertising and promotion costs, books and journals, prints and content production
Products of forestry, logging and related services (02)	Building materials, flowers
Radio, television and communication equipment and apparatus (32)	Mobilephones and mobilephone spare parts
Recreational, cultural and sporting services (92)	Recreation and leisure activities
Renting services of machinery and equipment without operator and of personal and household goods (71)	Leasing of computers, devices, machinery and equipment, rents on vehicles, work clothes and gas bottles and containers
Research and development services (73)	Analysis, consulting and expert services, other research subcontracting
Rubber and plastic products (25)	Disposable gloves and laboratory products
Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motorcycles parts and accessories	Machinery repair and vehicle related costs other than insurances
Wearing apparel; furs (18)	Work clothes

APPENDIX 2: BDe results of each EXIOBASE-category and explanations for fourfold

EXIOBASE Category	BDe	Number in the fourfold
Other business services (74)	1,36028E-08	1
Machinery and equipment n.e.c. (29)	1,29905E-08	2
Furniture; other manufactured goods n.e.c. (36)	8,03858E-09	5
Computer and related services (72)	5,62994E-09	4
Research and development services (73)	5,39369E-09	3
Chemicals nec	5,11318E-09	9
Electrical machinery and apparatus n.e.c. (31)	3,45016E-09	6
Renting services of machinery and equipment without operator and of personal and household goods (71)	3,13498E-09	8
Office machinery and computers (30)	1,90489E-09	11
Printed matter and recorded media (22)	1,8752E-09	7
Hotel and restaurant services (55)	1,6568E-09	12
Financial intermediation services, except insurance and pension funding services (65)	1,09396E-09	13
Health and social work services (85)	9,96301E-10	10
Radio, television and communication equipment and apparatus (32)	6,25393E-10	18
Rubber and plastic products (25)	4,82169E-10	19
Motor Gasoline	4,15293E-10	24
Other services (93)	3,287E-10	16
Membership organisation services n.e.c. (91)	3,27542E-10	15
Education services (80)	2,58735E-10	14
Other non-metallic mineral products	2,5736E-10	23
Oil/hazardous waste for treatment: incineration	2,555E-10	26
Wearing apparel; furs (18)	2,42738E-10	22
Recreational, cultural and sporting services (92)	2,23181E-10	17
Electricity nec	2,19764E-10	30
Other land transportation services	1,55304E-10	20
Construction work (45)	1,36034E-10	25

Insurance and pension funding services, except compulsory social security services (66)	1,04176E-10	21
Collected and purified water, distribution services of water (41)	4,14192E-11	28
Glass and glass products	2,22624E-11	31
Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motorcycles parts and accessories	2,20631E-11	26
Products of forestry, logging and related services (02)	1,60547E-11	33
Post and telecommunication services (64)	1,45595E-11	29
Air transport services (62)	1,31166E-11	34
Medical, precision and optical instruments, watches and clocks (33)	1,21959E-11	32
Food products nec	1,15722E-11	36
Plastics, basic	5,03344E-12	35
Ceramic goods	1,36355E-12	38
Paper and paper products	1,03537E-12	37
NA	0	-
SUM	**6,90735E-08**	-

APPENDIX 3: Full figure of fourfold field



APPENDIX 4: Global distribution of biodiversity footprint by different pressures

Biodiversity footprint caused by land use %	**Biodiversity footprint caused by terrestrial pollution %**	**Biodiversity footprint caused by water use %**	**Biodiversity footprint caused by freshwater P %**	**Biodiversity footprint caused by marine N %**
Guam 5,7	United Arab Emirates 19,2	United States 58,8	India 17,8	Estonia 79,01 *
Sao Tome and Principe 5,2	Italy 13,6	Australia 14,6	China 7,2	China 11,9
Northern Mariana Island 4,9	Palestinian Territory 13,0	Jordan 4,7	Brazil 6,2	Germany 4,2
Seychelles 4,6	Lebanon 9,9	Bahamas 3,7	Finland 4,3	United States 1,4
New Caledonia 4,0	Cyprus 7,9	Taiwan 1,9	Sri Lanka 4,1	Finland 1,2
Comoros 3,4	Papua New Guinea 7,2	Malaysia 1,5	Botswana 3,0	Netherlands 1,0
Mayotte 3,4	Qatar 3,9	Puerto Rico 1,1	Afghanistan 2,9	Sweden 0,9
Pitcairn 2,6	Montenegro 3,2	India 1	Panama 2,1	Lithuania 0,1
Finland 2,4	Oman 3,2	Yemen 0,8	Namibia 1,7	Latvia 0,1
French Polynesia 2,4	North Macedonia 2,2	Lebanon 0,8	Thailand 1,6	Belarus 0,03
American Samoa 2,4	Bhutan 1,1		Trinidad and Tobago 1,5	
Indonesia 2,3	Armenia 1,0		Malawi 1,4	
Reunio 1,8	Dominican Republic 1,0		Haiti 1,3	
Russian Federation 1,7	Mexico 1		Nepal 1,3	
Cape Verde 1,7			Venezuela 1,3	
Canarias 1,7				
Fiji 1,7				
Azores 1,5				
Mauritius 1,4				
Tonga 1,4				
Saint Helena 1,4				
Brazil 1,2				

* Estonia's contribution to marine pollution is disproportionately high, probably due to incorrect data in the LC-impact.

APPENDIX 4. Portfolio categorization

Portfolio category	**What is included**
Research equipment	Costs related to research and laboratory machinery and equipment, also leasing af machinery and repairs
Research materials	Materials related to research, including chemicals, gloves, glasses, components, products etc. and some services
Research services	Services related to research, including consulting, expert, analysis, audinting and maintenance and membership fees
IT services for research	IT related services, computers and mobilephones, software etc.
HR	Human resources. Meeting costs, meals, personnel gifts, health services and some administrative services, travel expenses
Facility	Rents, cleaning services, some maintenance services, waste management, freights, furniture, mailing, moves, reception services etc.
Infrastructure solutions	Data transfer and telephone costs. IT products
Communications	Advertising costs, media production and related services, some administrative services, translation services
IPR	Intellectual property rights
Security	Data security and guarding services
Knowledge discovery	Article processing fees, books, journals, information databases
Legal	Legal services, insurances
Quality	Eyeglasses, personnel protection, first aid equipment, freights