Enough is Enough

Living in the Sufficiency Space

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Abstract

Meeting basic human needs for all people worldwide without exceeding the Planetary Boundaries is the key challenge for sustainable development. Main drivers that must be addressed are consumption, affluence, and inequality (Rockström et al., 2023) and the ethical principle 'sufficiency' is suggested to be imperative. Planetary Boundary-based Life Cycle Assessment is well-suited for this endeavor. However, it currently lacks sharing principles grounded in sufficiency.

In this thesis I develop a new sufficiency-based sharing principle at a 'per capita' level for Denmark which is applicable to Planetary Boundary-based Life Cycle Assessment. As a first step, I conceptualize a Sufficiency Consumption Space for Denmark by a 'human needs floor' and an 'ecological ceiling', reflecting Decent Living Standards and the Planetary Boundaries. Based on this framework, I derive a new sufficiency-based sharing principle comprising of two sub parts: 1) The individual share of the global Safe Operating Space that is strictly reserved to satisfying Decent Living Standards per capita in Denmark and 2) The remaining individual Safe Operating Space that is left after satisfying the Decent Living Standards and staying within the ecological ceiling of the Planetary Boundaries. Notably, this remaining individual Safe Operating Space can be used freely by individuals for any consumption purpose.

Next, I conduct a bottom-up Life Cycle Assessment (LCA) to investigate the environmental impacts of 625 household consumption goods in Denmark. This analysis illuminates the relation between different consumption goods' and my newly developed sufficiency sharing principle. Finally, I suggest what consumption goods should be addressed from a sufficiency perspective by combining the LCA results with expenditure elasticities of Danish household consumption. This approach highlights the luxury goods with the highest environmental impact that can most easily be curtailed from a needs-based perspective.

Lastly, I find that Denmark is not currently on track for entering the Sufficiency Consumption Space. This thesis is conceptual and exploratory, providing a foundation for further research on the topic.

Keywords: *Sufficiency, Life Cycle Assessment (LCA), Planetary Boundaries, absolute sustainability, Human needs, Consumption Space, luxury consumption, sharing principle.*

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I would also like to express to my deepest gratitude to my girlfriend Marie for her loving support throughout this thesis project. It has been a wonderful time with you this spring – because we also had our first daughter, Karla. Finally, thanks to friends and family for your wonderful support as well.

"The stability and resilience of the Earth system and human well-being are inseparably linked" – Rockström et al. (2023)

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Abbreviations

CO2e: CO_2 equivalents

DLS: Decent Living Standards

GHG emissions: Greenhouse Gas emissions

IPCC: Intergovernmental Panel on Climate Change

LCA: Life Cycle Assessment

LCIA: Life Cycle Impact Assessment

PB-LCA: Planetary Boundary-based Life Cycle Assessment

1. Introduction

All people want to live a good life, yet the definition of a good life is inherently subjective. Given the diverse individual perceptions of what constitutes a good life, how can we ensure that everyone attains their personal vision of it? Furthermore, how can this be achieved within the limits of the Planetary Boundaries?

In this thesis, I will adhere to the fact that there are a limited set of basic human needs shared by all people across all cultures and generations. Thus, it is a global challenge to satisfy these basic needs for everyone to avoid serious harm and pursue a decent life. Currently, some 745 million people globally still lack access to electricity (IEA, 2023) and around 735 million people are undernourished (FAO et al., 2023). Also, 5.13 million people die each year by ambient air pollution from fossil fuels combustion (Lelieveld et al., 2023). This indicates that the basic needs of hundreds of million people remain unmet, preventing many from pursuing a good and decent life (Pirgmaier, 2020; O'Neill et al., 2018). This is, however, only one side of the global challenge for sustainable development.

The other side involves human pressures on the environment that exceed levels the natural Earth system domains can sustain, and the scale and urgency are unprecedented in human history. Rapid changes to the Earth system undermine critical life-support systems and risk triggering irreversible tipping points that could destabilize the Earth system (Rockström et al., 2023). For example, if climate change is not mitigated, current and future generations face the risk of self-amplifying global heat with potentially existential consequences (Steffen et al., 2018; Lenton et al., 2019; Armstrong McKay et al., 2022; Wunderling et al., 2022). UNEP (2023) warns that the world is heading towards 2.5-2.9°C global warming, translating to a global Safe Operating Space for climate change estimated at 2.51 billion tons CO2e per year, while current emissions are 47.9 billion tons CO2e per year. In Denmark, consumption-based GHG emissions are 13 tons CO2e per capita in 2023, needing a reduction to around 0.7 tons per capita by 2050 (Sanye et al., 2023).

Climate change is not the only environmental challenge though. Global material extraction has increased from 30 billion tons in 1970 to 106.6 billion tons in 2024 (UNEP, 2024) driven 90% by the four sectors Food, Built environment, Mobility, and Energy (electricity used in homes)(UNEP, 2024). Moreover, the rates of species extinction are at least tens to hundreds of times higher than the average the past 10 million years (IPBES, 2019). Also, it is estimated that 50% of the world population will be living in water-stressed areas by 2025 (Rammelt et al., 2023).

Considering this dual global challenge of meeting all basic human needs while staying within Earth's carrying capacity, the issue of distribution becomes central. This is because environmental impacts from consumption and lifestyles are not evenly distributed and there is a significant relationship between income and environmental footprints (Oswald et al., 2021; Starr et al., 2023). Therefore, addressing income inequalities is imperative for meeting basic human needs of all people within Earth's limited carrying capacity (Rammelt et al., 2023). Today, the 2,565 dollar-billionaires hold more wealth than the bottom 4.8 billion people (Rammelt et al., 2023), and the richest 1% of the world cause the same GHG emissions as the poorest 5 billion people (OXFAM, 2023). Over the past two decades, the 0.1% richest households have had a carbon footprint around 1,000 tons CO2e annually, compared to 100 tons CO2e or below for the lowest 99% (Starr et al., 2023)[1]. This income inequality is mirrored in material consumption with low-income countries averaging 2 tons materials consumed per capita in 2017 compared to 27 tons per capita in high-income countries (Akenji et al., 2021).

Narrowing the focus to Denmark, key trends over the past decade reveal increased environmental pressure from consumption in the key sectors Food, Housing, Mobility, and Energy. We build bigger houses, eat more meat, drive bigger cars, and we mostly use private passenger cars for transportation, often driving alone[2]. In terms of inequality, higher income level correlate with higher overall consumption level for almost any consumption category[3]. This confronts Denmark with placing limits on excess consumption because it hinders meeting the basic needs of people globally within the planet's ecological limits (Rammelt et al., 2023).

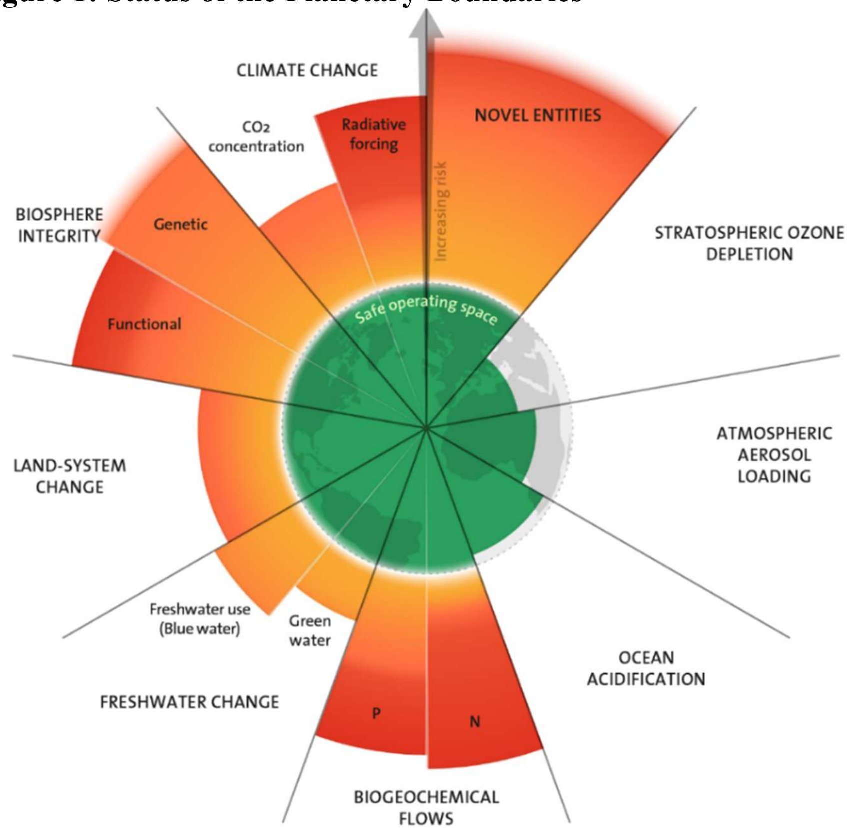
A well-established framework addressing nine critical environmental challenges is the Planetary Boundary framework, shown in Figure 1. It defines nine biophysical Earth system boundaries for human activity critical for maintaining biophysical stability of the Earth system over time. This protects the Earth's ability to support human societies and all other living organisms (Rockström et al. 2021). Thereby, the Planetary Boundaries delineate an "operating budget for humanity," or Safe Operating Space. Transgressing these boundaries risks triggering irreversible tipping points with detrimental consequences for modern society (Lenton et al., 2023; European Environment Agency et al., 2020).

Currently, six out of nine Planetary Boundaries are exceeded, with two core Planetary Boundaries - Climate Change and Biosphere Integrity - not even heading in the right direction (Lade et al., 2023). Importantly, the nine Planetary Boundaries interact as well. Specifically,

[1] by income
[2] The load factor of a passenger car in Denmark is around 1.3 (ref)
[3] Only very few exceptions.

human impacts on the environment are almost being doubled in magnitude by biophysically mediated interactions (Lade et al., 2023). Therefore, impacts from human activities on Earth systems must be considered in a systemic context where all environmental pressure categories are addressed – not only climate change (Richardson et al., 2023). This systemic approach will be a focus in my thesis.

Figure 1: Status of the Planetary Boundaries



Source: Richardson et al. (2023)

Fortunately, research indicate that it might be possible to achieve universal decent living for all within all planetary boundaries if societal efforts focus primarily on the satisfaction of basic human needs (Schlesier et al., 2024; Brand-Correa et al., 2017).

Taking a step back, what are the main drivers of these environmental challenges? Researchers highlight that unsustainable resource extraction and increasing consumption are primary drivers of drastic changes to the Earth system (Rockström et al., 2023). The IPCC supports this, saying that demand-side strategies have the potential to reduce global GHG emissions with 40-70% in the building-, land transport-, and food sectors by 2050 (Creutzig et al., 2022). Furthermore, the latest IPCC report states that affluence is "by far the strongest upward driver for climate change" (Creutzig et al., 2022).[4] For instance, global textile production per-capita has increased from 5.9 kg to 13 kg per year between 1975–2018 (Niinimaki et al., 2020). Thus, addressing affluence, consumption, and inequality is crucial. But, what about all the technological development that has ocurred? For decades, efficiency gains have been outpaced by an absolute increase in affluence (Wiedmann et al. 2020; Xia et al. 2021 in Creutzig et al., 2022) [5].

So, what scientific methods can be utilized to address these challenges? Traditional Life Cycle Assessment (LCA) is widely applied to quantify the life cycle impacts of anthropogenic systems; however, it falls short in linking human needs to the limited carrying capacity of Earth's ecosystems. Therefore, the subcategory of LCA methods called Planetary Boundary-based LCA (PB-LCA) is needed. This method quantifies whether environmental pressures from any given human activity at any scale can be considered environmentally sustainable in relation to the Planetary Boundaries. A crucial step in PB-LCA is determining how much environmental impact any activity is "allowed to claim" as a share of the Earth's total carrying capacity. Operationalizing this involves using sharing principles to assign a normative share of the global Safe Operating Space to human activities at any scale, be it countries, sectors, companies, individuals, or products (Perdomo Echenique et al., 2022). Deciding on the allocation of Earth's limited carrying capacity between all human activities is an immensely complex process, involving biophysical, socioeconomic, ethical, political and cultural perspectives (Bai et al., 2024). Although a niche research area, the importance of developing adequate sharing principles in PB-LCA is underlined by the fact that the choice of sharing principle significantly influences research conclusions (Ryberg et al., 2020). Thus, sharing principles have far reaching implications for the results, recommendations, and decision-making that occurs based on the PB-LCA.

On this background, I will pursue the development of a new sharing principle for PB-LCA that embraces the global dual challenge of meeting all people's basic needs while not transgressing any of the nine Planetary Boundaries. I will argue this puzzle can only be solved if the sharing principle is based on the ethical principle 'sufficiency'. The main tenet of 'sufficiency' in sustainable development is that satisfying the basic needs of all people must be strictly prioritized, so everyone can pursue a decent life (Gough, 2017b). Therefore, for the sharing principle to align with sufficiency, it should first reserve and allocate the shares of the

[4] As measured by GDP per capita.
[5] Measured in GDP per capita.

Safe Operating Space needed to satisfy basic human needs for all people. Subsequently, it should distribute the remaining Safe Operating Space equally among all people for other consumption purposes. In practice, however, assigning a theoretical equal right to claim the remaining Safe Operating Space does not ensure that it will happen in real-life.

Due to the interdisciplinary nature of developing a sharing principle, I will draw upon several topics such as Human Need theory, Decent Living Standards, Consumption Corridors, Planetary Boundaries, Absolute LCA, inequality, distributive justice theory, and household budget surveys. This approach will establish a systematic and comprehensive link between human needs, global resource use, environmental impacts, and Planetary Boundaries.

Finally, sufficiency-based sharing principles in PB-LCA remain largely unexplored in the LCA literature (Hjalsted et al., 2021). Therefore, this thesis represents one of the first attempt to incorporate Planetary Boundaries, Decent Living Standards, consumption, sufficiency, and inequality in an integrative framework, with Denmark as the case study. This leads to the problem statement of my thesis.

2. Research question

The objective of this thesis is to develop a sufficiency-based sharing principle for Planetary Boundary-based Life Cycle Assessment and to enlighten its implications in the context of Denmark. To pursue this, the following main research question and sub-questions are defined.

Main research question:

How can a new sufficiency-based sharing principle be developed for Planetary Boundary-Life Cycle Assessment (PB-LCA) that ensures the satisfaction of basic human needs for everyone while respecting all Planetary Boundaries?
And what are the implications of this principle for consumption patterns in Denmark?

To answer my main research question, I have defined several sub questions (SQ) that will lead to answering it. I will address them consecutively:

SQ 1	What is my pre-analytic vision related to answering the main research question?	Pre-analytic vision Section 3
SQ 2	What theoretical insights are needed for addressing the main research question?	Theory Section 4
SQ 3	What is the status of sufficiency-based sharing principles in the PB-LCA literature?	Literature review Section 4.7
SQ 4	How can a new sufficiency-based sharing principle be developed that reflects staying within all Planetary Boundaries and satisfying basic needs?	Analysis Section 5.1
SQ 5	What is the environmental impact of Danish household consumption? And how does it compare to the sufficiency sharing principle?	Analysis Section 5.2
SQ 6	What consumption goods should be focused on when analyzing the degree of luxury and environmental impacts of consumption?	Analysis Section 5.3
SQ 7	What is the research contribution and implications of my investigation? And what are the strengths and limitations?	Discussion Section 6

In brief, this will lead to the following way of answering:

SQ 1	Explicate my underlying worldview and assumptions concerning economics of sustainable development	Pre-analytic vision Section 3
SQ 2	Eudaimonic wellbeing, Theory of Human Need, Decent Living Standards, Consumption Corridors, Planetary Boundaries, Life Cycle Assessment	Theory Section 4
SQ 3	Literature review finds only a few existing sufficiency-based sharing principles for Planetary Boundary-based Life Cycle Assessment	Literature review Section 4.7
SQ 4	The sufficiency sharing principle involves prioritizing a share of safe operating space to meeting Decent Living Standards for all people. Then, the remaining share of safe operating space can be used for any consumption purpose chosen by the individual.	Analysis Section 5.1
SQ 5	Conduct a bottom-up LCA of the environmental impact potentials of all consumption goods of Danish annual household consumption	Analysis Section 5.2
SQ 6	Combine expenditure elasticities and LCA from SQ 5 to reveal goods with highest degree of luxury and environmental impact, using average annual consumption levels per good	Analysis Section 5.3
SQ 7	Discussing the research contribution and implications of my investigation. Discussing the strengths and limitations to my thesis	Discussion Section 6

2.1 Personal motivation

The idea for my thesis emerged from reading PB-LCA literature, for example Heide et al. (2023) and Bai et al. (2024). My initial interest was in applying PB-LCA for answering questions about sustainable development. When diving into the literature I realized that sharing principles play a pivotal role for the outcome and recommendation of any PB-LCA due to its normative character. Additionally, I recognized that 'sufficiency' is an ethical perspective well-suited for achieving sustainable development, as it encompasses both human needs and the Planetary Boundaries. However, it became evident that sufficiency-based sharing principles are scarce and largely unexplored in PB-LCA literature. For that reason I am contributing to that research area by proposing a new sufficiency-based sharing principle.

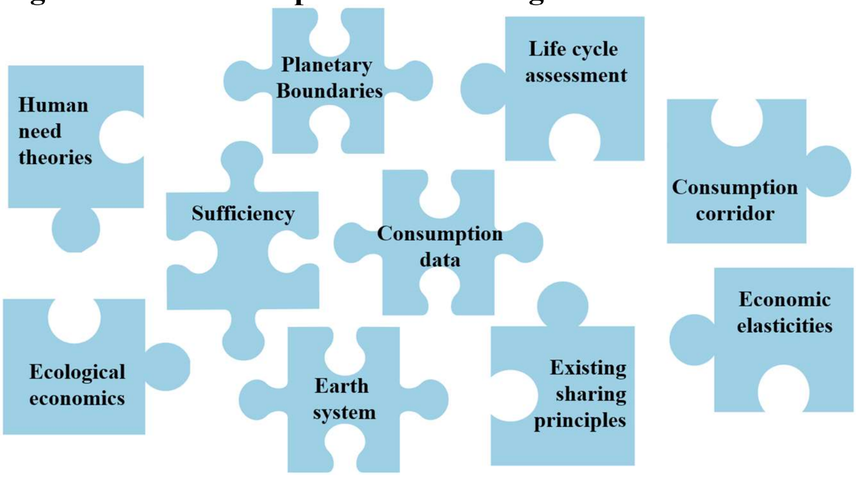
2.2 Disclaimer to the reader

As I am developing a new sufficiency-based sharing principle drawing upon several topics and methods, it is important to emphasize that the outcome of this thesis is primarily conceptual and explorative. It will not present a fully developed sharing principle ready for application, nor will it be the definitive sufficiency sharing principle. Much more research is needed in this area, and I hope my thesis will provide a foundation for further work.

2.3 Literature search

I oriented myself in the literature of several research areas to get an overview of different topics that could be combined and to get a sense of where the areas are currently heading. Specifically, I looked through literature on the topics in Figure 2.

Figure 2: Research topics that I investigated



My method of literature search was primarily 'snowballing'. This implied starting with a few key studies as "seeds" and then identifying other relevant studies back in time through its reference lists, and forward in time through citations, as well as suggested related studies, using Scopus. Also, I looked up other articles by an author when encountering a relevant article. This was through Google Scholar. I did traditional string search as well[6], but most of my articles used in the thesis were found by snowballing. In total, it became evident that several topics were necessary for answering my main question.

Before outlining the theory used for my investigation, I will be transparent about my pre-analytic vision – a term coined by the "founder" of Ecological Economics, Herman E. Daly (1991). This involves being transparent of my underlying worldview and assumptions that I apply between the lines in my investigation. I find it important because the initial perception of a problem is decisive for which methods to use and the solution space emerging from it. My pre-analytic vision is primarily founded in ecological economics, so Section 3 is reflecting main perspective of ecological economics that I draw upon. This will be made clear in the next section and help explaining the way I have initially addressed my research question.

3. My pre-analytic vision

3.1 A growing economic subsystem in a "full world"

In ecological economics, the global macroeconomy is viewed as an open subsystem of the global ecosystem in terms of materials and energy. Importantly, the global ecosystem is finite, materially closed and nongrowing (Costanza et al., 2015). Consequently, the global macroeconomy is fundamentally dependent upon the overall ecosystem, both as a source of inputs of useful low-entropy ("useful") matter and energy, and as a sink for high-entropy ("non-useful") waste and energy. Therefore, there are physical limits to the biophysical throughput of resources from the ecosystem through the economic subsystem and back to the ecosystem as waste (Costanza et al., 2015). More specifically, the global ecosystem has a limited capacity to regenerate low-entropy inputs and to absorb high-entropy waste to sustain the global economic subsystem. As the global economic subsystem has grown drastically relative to its host system – the global ecosystem - it has become unsustainably large relative to the global ecosystem that sustains it.

3.2 Sustainable scale, fair distribution, and efficient allocation

Given the "full world" context, ecological economics identifies three basic economic problems to solve for achieving sustainable development (Daly, 1992): Scale, distribution, and allocation.

[6] See the search string in Appendix 1.

Scale means "the size of the physical volume of the throughput from the environment as low-entropy raw materials and back to the environment as high-entropy wastes" (Daly, 1996). Mathematically, the total scale of the economy may then be thought of mathematically as population times per capita resource use. Since the global macroeconomy is fundamentally dependent on the carrying capacities of the global ecosystem, it has an optimal scale beyond which it cannot be sustainably supported by its host system (Daly, 1996).

Distribution refers to "the relative division among people of the total resource flow embodied in final goods and services" (Daly, 1996). A good distribution is one that is just or fair, or at least one in which the degree of inequality is limited within some socially accepted range.

Allocation concerns the "relative division of the resource flow among alternative product uses". A good allocation is one that is efficient, more specifically Pareto-efficient (Daly, 1996).

The three components of the economic problem for sustainable development - sustainable scale, fair distribution, and efficient allocation - are highly interrelated (Daly 1992). Scale should be determined by social decisions that reflect ecological limits, such as the Planetary Boundaries framework. Distribution should also be determined by social decisions that reflect a just distribution of resources. Subject to these social decisions, the market can then allocate scarce resources efficiently, at least in theory. While there are an infinite number of efficient allocations, only one exists for each distribution and scale. Importantly, an efficient allocation does not guarantee sustainable development in itself (Costanza et al., 2015).

These three problems should be solved in the following order: First, establish the ecological limits of sustainable scale and implement policies to ensure that the throughput of the economy stays within the regenerative and assimilative capacities of the global ecosystem's sources and sinks. Second, establish a fair and just distribution of resources through systems of property rights and transfers. Third, use market-based mechanisms to allocate resources efficiently (Costanza et al., 2015).

3.3 Economic growth and development

Ecological economics distinguishes between increased total throughput of matter and energy referred to as *growth,* and efficiency improvements referred to as *development.* Growth depletes more total natural capital and beyond some point the marginal cost per additional growth will exceed the marginal benefits for human development because of the increasing negative effects on the environment. Beyond this theoretical point, growth will impoverish human wellbeing rather than enriching it, according to ecological economics (Costanza et al., 2015). Development, on the other hand, does not – all else equal - deplete more depletion of natural capital. However, I will comment on this in the discussion.

Admittedly, economic growth would not pose the same problem if it could be sufficiently decoupled fast enough from the increasing environmental pressures – known as 'sufficient absolute decoupling' or 'green growth'. However, numerous studies and reviews have provided empirical support that it is highly unlikely to happen, lacks empirical support, and is a risky strategy for sustainable development (Vogel et al., 2023; Cuny et al (2024); Hickel et al., 2020; Haberl et al., 2020; Parrique et al., 2019; Fix, 2019; Tilsted et al., 2021; Costanza et al., 2015; Wiedmann et al., 2013; Heun et al. (2019); Lange et al., 2020; Ward et al., 2016; Coscieme et al., 2019; Wiedenhofer et al., 2020).

3.4 Sustainable development

Since "sustainable development" have become a widely used concept in all areas of society, I will make it clear how I understand them. The Brundtland Report famously defined sustainable development as "development that meets the needs of the present without compromising the ability of the future to meet their own needs" (O'Neill et al., 2018). The report goes on saying that sustainable development makes necessary the "the concept of needs (…) and the idea of limitations". Thus, satisfying human needs is critical to achieving sustainable development. Sustainable development can also be seen from a universal human rights perspective with the UN Declaration of Human Rights saying that "everyone has the right to a standard of living adequate for the health and well-being of himself, including food, clothing, housing and medical care and necessary social services." (United Nations, 1948 in Heide et al., 2024).

However, I will supplement the above focus on human needs with the definition of sustainable development by Herman Daly because he adds more nuance on resource use. According to Daly (1996), sustainable development demands that "the global economic subsystem must not grow beyond the carrying capacity within which it can be permanently sustained or supported by the containing ecosystem". This means that we cannot use raw material inputs at a rate faster than it can be regenerated or than we can develop substitutes for it, and we cannot generate waste faster than it can be absorbed by ecosystems. Although substitutes exist for many things, there are several areas where they do not: Fresh drinking water, clean air, phosphorus for food production, loss of species, to name a few.

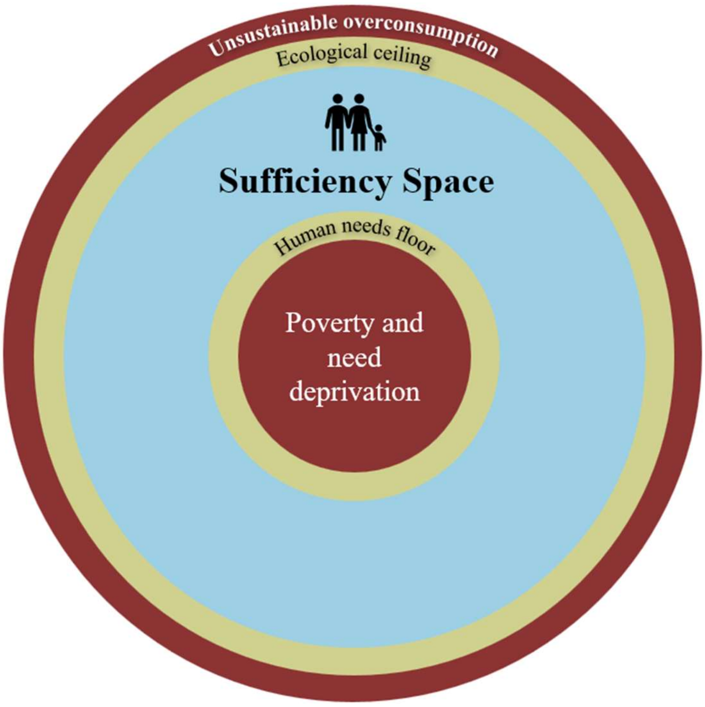
Summing up, sustainable development means satisfying the needs of all people while living within environmental constraints of regenerative and absorptive capacities (Costanza et al., 2015). This understanding aligns well with the view of sustainability in PB-LCA. Bjørn et al. (2015) define environmental sustainability by the term ‘carrying capacity’ which they define as “the maximum sustained environmental intervention a natural system can withstand without experiencing negative changes in structure or functioning that are difficult or impossible to revert”. In sum, my pre-analytic vision of sustainable development thereby fluctuates with the view inherent to PB-LCA.

A similar understanding of sustainable development is proposed by Kate Raworth’s Doughnut framework[7]. According to Raworth (2017), the overall goal of societies should be to “meet the needs of all people within the means of the planet”. This is very similar to my way of understanding it. Moreover, Raworth highlights that there exists no empirical evidence that any society is or has been operating within a Safe and Just Space for humanity (O’Neill et al., 2018). That is, high-income countries succeed in achieving most social minimum thresholds, but they exceed environmental pressure levels (Fanning et al., 2020). The only difference to Raworth’s Doughnut framework is that I will not apply the same social indicators. Raworth (2017) applies the Sustainable Development Goals to define social minimum threshold indicators, including “peace”, “corruption”, “political voice”, and “gender equality”. I will not include these more social indicators for investigating human needs, and the reason will become clear in the theory section.

The following Figure 3.1 illustrates the overall vision of sustainable development that I will endorse[8]. It depicts the ecological ceiling and the social foundation within which the safe and just space for humanity lies – I will define it “a Sufficiency Space”. When not meeting the lower thresholds of basic human needs, poverty and need deprivation occur. Contrarily, when overshooting the environmental ceiling an environmentally unsustainable state occurs for humanity.

[7] which is not surprising since she is an ecological economist
[8] Again, it is similar to the Doughnut, but not exactly the same when looking at quantitative indicators

Figure 3.1: The Sufficiency Space for sustainable development



Source: Own illustration. Inspired by Wiedmann et al. (2020).

I have now outlined the key aspects of my pre-analytic vision: The growing economic subsystem, the economic challenge of sustainable scale, fair distribution, and efficient allocation, and finally my perspective on sustainable development. This pre-analytics vision informs my choice of theory in the next section, which is essential to answer my main research question.

4. Theory

"What is important from the point of view of sufficiency is not that everyone should have the same, but that each should have enough. If everyone had enough, it would be of no moral consequence whether one had more than others" (Meyer et al., 2006)

4.1 Hedonic- and eudaimonic wellbeing

Wellbeing is in research and policy equated to many concepts, such as 'happiness', 'life satisfaction', 'subjective wellbeing', 'economic welfare', 'prosperity', 'thriving' or 'flourishing'. The way 'wellbeing' is operationalized will have decisive impact on the possible outcomes of analysis and recommendations (Brand-Correa et al., 2017). There are basically two schools of thought within wellbeing research - hedonic and eudaimonic wellbeing.

The hedonic approach is known as “subjective wellbeing”, and the eudaimonic approach is known as “need-based wellbeing”. I will follow the eudaimonic wellbeing approach as my theoretical foundation. In general, eudaimonic wellbeing suggests that a decent life is not about the satisfaction of every subjective individual desire because some desires are morally preferable to others. Thus, eudaimonic wellbeing highlights a crucial distinction between “needs” and “wants or desires”. Moreover, basic needs are regarded universal for all humans across time and space and satisfying these is a necessary *precondition* for human wellbeing. Not satisfying them will cause objective harm to any individual because of basic human physiological requirements (Doyal et al., 1991).[9]

Elaborating on a concrete minimum set of needs is inherently complex and entails scientific, ethical, political, and normative challenges. I will primarily rely on the efforts of Doyal et al. (1991) and later research based hereupon. The are two reasons for that: First, Doyal et al. (1991) is one of the most well-established theories to specify a concrete set of universal basic needs and universal need satisfiers. Second, and more importantly, it has allowed later studies to quantify the direct material- and energy requirements for meeting the basic needs (Rao et al., 2018; Millward-Hopkins et al., 2020; Schor, 2023).

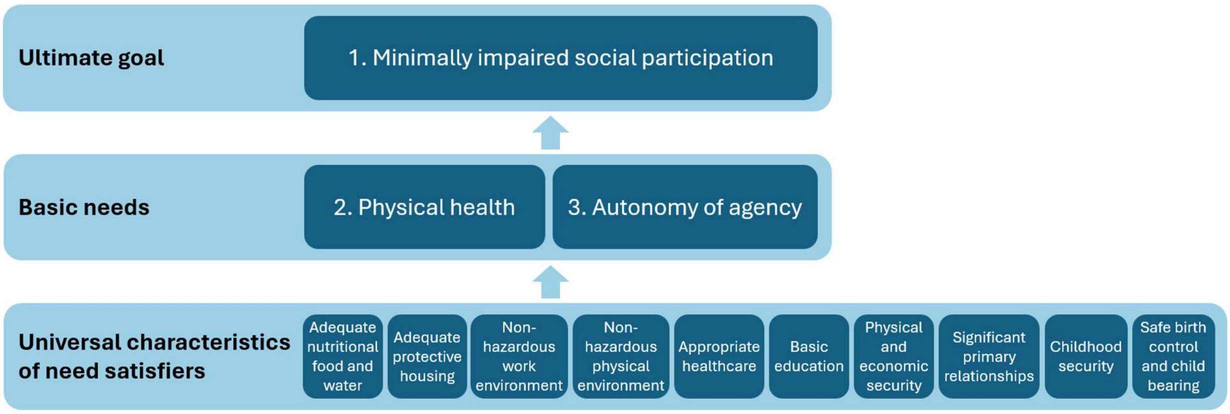
In this way, Rao et al. (2018), Millward-Hopkins et al. (2020), and Schor (2023) bridge the gap between having a recognized basic needs theory on the one hand (Doyal et al., 1991) and quantifying the material- and need requirements for meeting those needs on the other hand. Specifically, I will use the outcome of Schor (2023) in my analysis. I will combine this with the concept of a Consumption Corridor (Fuchs et al., 2021) to conceptualize a so-called ‘Sufficiency Consumption Space’ for Denmark, which will lead to the derivation of my new sufficiency-based sharing principle. Summing up, this is the key reason for positioning my analysis directly behind Schor (2023), Millward Hopkins et al. (2020) and Rao et al. (2018), who are ultimately based on Doyal et al. (1991). In the following, I will briefly elaborate on the Theory of Human Need by Doyal et al. (1991) to outline the theoretical foundation of my investigation. Subsequently, I will describe two concepts derived from the Theory of Human Need, namely Decent Living Standards (Rao et al., 2018) and Consumption Corridors (Fuchs et al., 2021).

[9] In contrast, hedonic wellbeing is based on people’s subjective wants and desires, and they do not express necessary objective preconditions for an individual’s ability to flourish in society.

4.2 The Theory of Human Need

The Theory of Human Need by Doyal et al. (1991) was published in 1991 and has been further developed since then. Its key concepts are depicted in Figure 4.1 below. The basic idea is that all humans across all cultures, in the present and future, have some universal basic needs. These must be met for all people to avoid serious harm so they can participate socially in society. Doyal et al. (1991) identify three universal basic human needs: Health, Autonomy, and Social participation. 'Health' is referred to as "freedom from chronic disability, disease, and impairment of cognitive function" (Rao et al., 2018). 'Autonomy' is defined as "the ability to make competent informed choices about what to aim for in life and how to go about doing it" (Rao et al., 2018). From autonomy follows the ability to learn, work, engage in and reflect upon culture and society, and enjoy leisure. In combination, 'Health' and 'autonomy' enable "minimally impaired participation in social life", which is the ultimate universal goal of human activity, according to the theory (Doyal et al., 1991).

Figure 4.1: The Theory of Human Need



Source: Inspired by Gough (2015)

Inevitably, certain levels of consumption are needed to satisfy the basic needs. Doyal et al. (1991) stress the importance of distinguishing consumption that satisfies human needs from consumption that does not. The key is what happens in deficiency of it. For example, decreasing consumption that is related to basic human needs results in objective harm and deprivation to the individual's life chances and social participation. On the contrary, a decrease in consumption that only serves wants and desires might result in subjective discomfort, but not in objective physical harm or impairment in the ability to participate in society (Brand-Correa et al., 2020).[10]

Another key aspect of the Theory of Human Need (Doyal et al., 1991) is the distinction between 'needs' and 'need satisfiers'. While the basic needs are ends in themselves, 'need satisfiers' are the means to satisfy the needs. Crucially, while human needs are spatially and temporally universal and finite, the ways in which they are satisfied may be immensely diverse. Need satisfiers vary with individual circumstances, technological access, infrastructure, geography, cultural norms, societal institutions, and over time. For instance, there are numerous different cuisines across the world providing nutritious food for the basic need of health.

To bridge the universality of the basic needs with the immensely diverse nature of need satisfiers, Doyal et al. (1991) identify all the universal characteristics that need satisfiers have in common over time and space.[11] This results in 11 universal characteristics of need satisfiers, shown in Figure 4.1[12]. Moreover, this enabled quantifying the universal characteristics of need satisfiers empirically as 'Decent Living Standards. These will play a key role in deriving the sufficiency sharing principle. Therefore, I will elaborate on the Decent Living Standards in the following section (O'Neill et al., 2018).

The Theory of Human Need (Doyal et al., 1991) implies six theoretical characteristics of the basic needs, shown in figure 4.2. Thus, the basic human needs are objective, plural, non-substitutable, satiable, cross-generational, fair, and just. A further elaboration of these characteristics is given in Appendix 2.

Figure 4.2: Six characteristics of basic human needs

Source: Own illustration

[10] To be noted, people may still believe that all their consumption is an act in pursuit of subjectively perceived needs, while essentially being wants and desires (Di Giulio et al., 2014).
[11] It is this sharp distinction between universal needs and contextual need satisfiers that prevents the theory from being accused as paternalist, intrusive, and culturally insensitive (Doyal et al., 1991).
[12] Physical and economic security are pooled in Figure 4.1 for fitting the layout.

With these six characteristics the Theory of Human Need (Doyal et al., 1991) provides support for the ethical distributive principle of 'sufficiency', which entails bringing all people up to thresholds where basic needs are sufficiently satisfied. 'Sufficiency' also demands prioritizing basic needs over excessive subjective wants – in line with eudaimonic wellbeing - and for distributing resources more equally given Earth's limited resources and severe transgressions of Planetary Boundaries. Meyer et al. (2006) highlight sufficiency as: "Each individual should reach some absolute level - the threshold level of sufficiency - and the value of reaching this level is independent of whether other individuals are above or below this threshold. […] The distinctive feature of this view is that there is a threshold and that benefiting people below the threshold has absolute priority compared to benefiting people above the threshold" (Meyer et al, 2006).

I will apply this perspective of 'sufficiency' in my conceptualization of a 'Sufficiency Consumption Space' for Denmark and the derivation of a sufficiency-based sharing principle.[13]

4.3 Decent Living Standards

Introduced by Rao et al. (2018), the Decent Living Standards (DLS) operationalizes the universal need satisfier characteristics from Theory of Human Need (Doyal et al., 1991). It relies directly on the Theory of Human Needs (Doyal et al., 1991) but improves the specificity by defining a concrete and elaborate list of *material* requirement indicators of the universal need satisfier characteristics. Specifically, Rao et al. (2018) put forward 11 material dimensions of the Decent Living Standards[14]. However, Rao et al. (2018) do not quantify the 11 material indicators of the DLS dimensions. This is undertaken by Millward-Hopkins et al. (2020) who estimate the minimum threshold amount of energy use required to provide Decent Living Standards to the global population. Two years later, in 2022, they refined the model by including scenarios of global inequality in addition to the strictly egalitarian DLS inventory (Millward-Hopkins, 2022). In his master's thesis, Schor (2023) collaborated with Joel Millward-Hopkins to use process-based LCA to estimate all the environmental impacts related to the model proposed in Millward-Hopkins et al. (2020). As a part of his thesis, he modelled

[13] This is in direct contrast to saying that individuals should have opportunities to acquire endless wants (Fuchs et al., 2021).
[14] These are shown in Appendix 3.

the specific environmental impacts of satisfying Decent Living Standards for all people in Denmark[15].

In a new study, Schlesier et al. (2024) similarly quantify the environmental impacts of providing the materials and energy needed to satisfy Decent Living Standards for all people. Their study includes a scenario of technological change by modelling a global fossil-free energy system, a global pescetarian diet, wood-based buildings, no cropland expansion, and low demand for basic needs. The strength of Schlesier et al. (2024) lies in incorporating scenarios of technological implementations of known technologies and behavioral shifts, which Winter-Schor (2023) did not. However, Schlesier et al. (2024) aligns with the Doughnut framework. This is disadvantageous for my study since I would like to compare the basic human needs to all the Planetary Boundaries, which is essential for deriving my 'Sufficiency Consumption Space' and the new sufficiency sharing principle. Therefore, I will apply the DLS model developed by Schor (2023) in collaboration with Joel Millward Hopkins. In the following section, I will elaborate on the important role of including aspects of inequality in Decent Living Standards.

4.3.1 The role of inequality

The motivation for including economic inequality in Millward-Hopkins et al. (2022) is that current levels of economic inequality translate into inequality in consumption, which causes inequality in material use and finally results in inequality in environmental impacts. Thus, the responsibility for exceeding numerous Planetary Boundaries is unequally split between different consumption levels. Numerous studies have shown that the rich are disproportionately responsible for exceeding the Planetary Boundaries (Otto et al., 2019; Wiedmann et al., 2020; Starr et al., 2023).

For example, Ivanova et al. (2016) show that total household expenditure is highly positive correlated with carbon footprint, land footprint, material footprint and water footprint. Also, it is found that inequality substantially increases the energy requirements for securing Decent Living Standards for a global population (Millward-Hopkins, 2022). The intuition is simple: If all people must be raised above a certain threshold for meeting basic needs, then adding inequality on top of that increases the total energy required.

As an example, it is estimated that if total global energy use is reduced enough to get back within the planetary boundary for climate change, but current global energy inequality

[15] All the Decent Standard Living inventories mentioned can be found in Appendix 3.

remains, then more than four billion people will not have access to decent levels of energy (Millward-Hopkins et al., 2023). Therefore, it is argued that addressing inequality is most likely necessary to secure Decent Living Standards for all people within the Planetary Boundaries. Unfortunately, Schor (2023) has not included the inequality scenarios of Millward-Hopkins (2022) in his thesis, so it will not be modelled directly in my Sufficiency Space for Denmark. Finally, the relevance of using the Decent Living Standards framework has also been supported by the IPCC in their recent Working Group III contribution to the Sixth Assessment Report (2022, p. 509).

The Decent Living Standards studies (Rao et al., 2018; Millward-Hopkins et al., 2020, 2022; Schor, 2023) address minimum material requirements threshold of satisfying human needs, but they do not compare it to the Planetary Boundaries[16]. Therefore, I will employ the framework of Consumption Corridors that embraces Decent Living Standards as a social minimum threshold ('floor') and the Planetary Boundaries as an ecological maximum ('ceiling'). I will briefly elaborate on this in the following.

4.4 The Consumption Space

"The only exit from the 'polycrisis' is a corridor of sufficiency between meeting needs and avoiding excess" – Bärnthaler and Gough, 2024

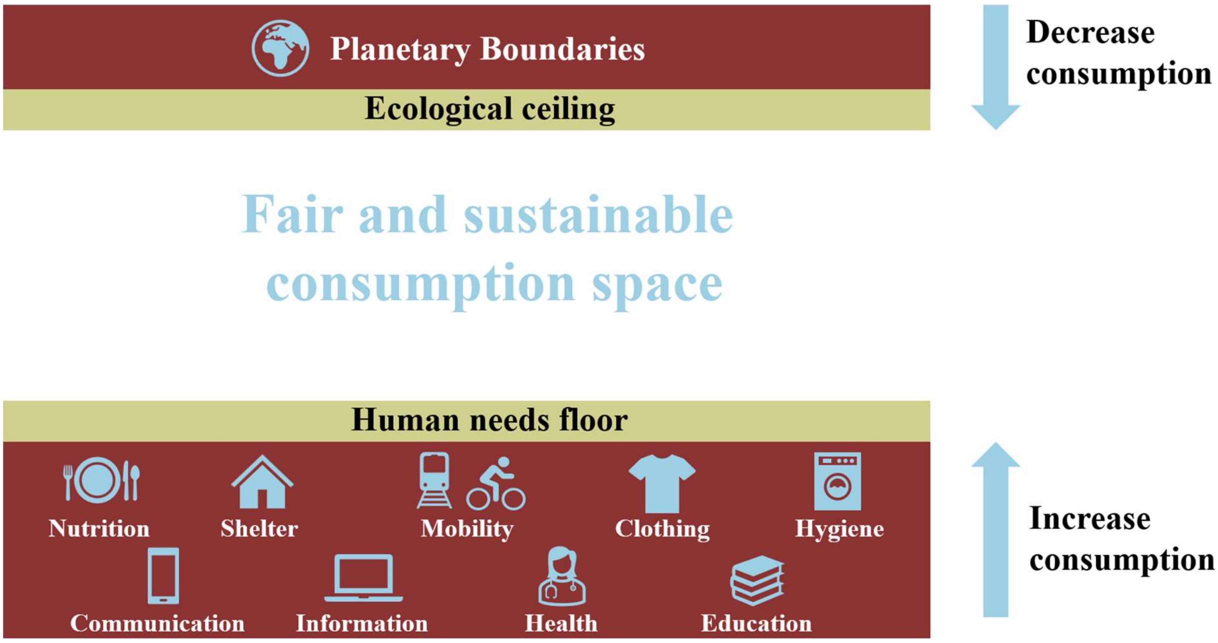
The framework of a Consumption Corridor is put forward by Fuchs et al. (2014, 2021). It has been referred to as a consumption *corridor* or as a consumption *space*. I find it most intuitive to communicate consumption *space*, so I will refer to that. The Consumption Space describes a sustainable, fair, and environmentally Safe Operating Space for humanity. It is located above a "social floor" of minimum consumption standards that reflects meeting Decent Living Standards for all people, and below an "ecological ceiling" of maximum consumption derived from not transgressing Planetary Boundaries. It is illustrated in Figure 4.3 below. The ecological ceiling implies a limit on people's total use of natural resources, which is necessary to guarantee access to a sufficient level of materials and energy for everyone to meet their basic needs (Fuchs et al., 2021).

In combination, the floor and the ceiling form a sustainable Consumption Space in which people can live freely and environmentally sustainable according to their individual

[16] This is only done in the most recent study, Schlesier et al. (2024).

perceptions of a good life (Fuchs et al., 2021). Specifically, I will refer to the framework as a Sufficiency Consumption Space because it is the operationalization of 'living in sufficiency', as argued earlier.

Figure 4.3: A fair Consumption Space for sustainable lifestyles



Source: Own illustration. Inspiration from Akenji et al. (2021)

Herman Daly was supporting this idea as well. He advocated maximum consumption restrictions, and his logical argument goes: "If you have a limited total (the Planetary Boundaries), and you also have a minimum (satisfying basic needs), then that necessarily implies a maximum (consumption) somewhere" (Daly, 2018). In a recent report, Akenji et al. (2021) supports the idea in relation to climate change: "With a global absolute cap on emissions, overconsumption by one person affects the prospects of another, and encroaches into another's consumption space, requiring collectively working toward a more equitable distribution of limited carbon budgets". These two quotes thereby support the idea of restricting excess consumption to allow ecological space to meeting basic needs for all, now and in the future.[17] Naturally, minimum- and maximum consumption standards cannot be defined once

[17] This is a point where my use of the Consumption Space theory (Fuchs et al., 2021) differs from Schlesier et al. (2024) in addressing excess consumption explicitly.

and for all because the culturally agreed consumption goods to satisfy basic needs in today's world reflect current unsustainable provisioning systems (Di Giulio et al., 2021).[18]

If meeting Decent Living Standards for all people within the Planetary Boundaries implies a maximum level of sustainable consumption, then whose consumption should be curbed when a country is exceeding the Planetary Boundaries? Naturally, there is no unequivocal answer to that, so I will suggest a possible way of addressing it in my analysis. Specifically, I will suggest measuring the 'degree of luxury' for all goods on a spectrum from highly necessary to highly luxurious consumption. According to Shue (1993), this distinction between necessities and needs is important because it can be seen as profoundly unjust to keep allowing excess consumption of the richest while not satisfying basic human needs for the poorest. This is echoed by Gough (2017) who argues that the most effective and fair way to reduce consumption levels to get back within the Planetary Boundaries is to distinguish need-based 'sufficiency consumption' from 'luxury consumption'. He argues that strategies to reduce excess consumption have become an imperative, starting in the global North (Creutzig et al. 2018). This is stressed by Millward-Hopkins et al. (2021) who state that: "Since income is a key determinant of ecological impacts, the Global North and wealthier classes elsewhere are primary drivers of global ecological pressure."

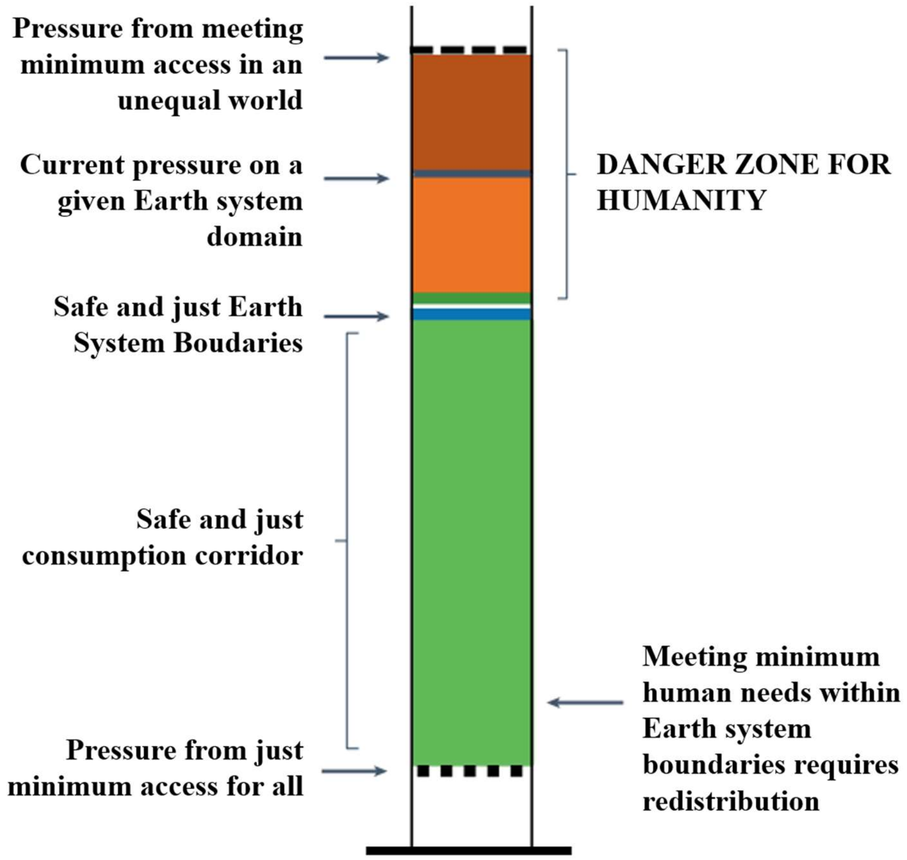
My focus on investigating excess consumption is shared by the IPCC in Creutzig et al. (2022). They state that "demand-side measures to decrease overconsumption must be fair, meaning prioritizing universal basic needs over consumers' subjective preferences and wants" (Creutzig et al., 2022). Furthermore, "minimum and maximum standards of sustainable consumption corridors […] and a distinction between necessities and luxuries can realize the potential of living well within ecological limits" (Creutzig et al., 2022).

Putting a figure on it, Gupta et al. (2023) have estimated that further climate change impact from meeting decent living access to the 62% of the global population currently lacking access, equals the existing climate impacts from the lifestyles of the wealthiest 4% people. Therefore, they suggest reserving a minimum of materials and energy to secure access to decent living for all, visualized in Figure 4.3. This is similar to how I will derive the sufficiency sharing principle in the analysis. Furthermore, Gupta et al. (2023) conclude that "wealthy individuals contribute disproportionately to higher GHG emissions and have a high potential for emissions reductions while maintaining decent living standards and well-being" (Creutzig et al., 2022). I

[18] Therefore, they must be recalibrated over time according to changing social, cultural, technological, and ecological developments (Fuchs et al., 2021). For this, a combination of 'expert knowledge' and active citizen involvement is suggested.

will use this argument as the reason for why luxury goods with a high environmental impact should be curbed; they are very environmentally harmful and can be curbed rapidly with a minimum risk of significantly impacting people's Decent Living standards.

Figure 4.3: Creating a Sufficiency Space



Source: Gupta et al. (2023)

To reach the sustainable consumption space, Creutzig et al. (2022) also refer to the ethical norm of 'sufficiency', which they define as "a set of measures and daily practices that avoid demand for energy, materials, land, and water while delivering human well-being for all within all Planetary Boundaries". This way of operationalizing 'sufficiency' aligns with Gough (2023) who defines 'sufficiency' as the space between the 'floor of necessity' and below the 'ceiling of excess'. Furthermore, he states that the 'human needs floor' in rich countries in the Global North implies identifying necessary goods and impacts while the 'ecological ceiling' implies defining and curbing luxuries (Gough, 2023). Following in the footsteps of the mentioned researchers (Daly ,1996: Akenji et al., 2021; Fuchs et al., 2021; Gough, 2017; Creutzig et al., 2022; Gupta et al., 2023) I will operationalize a Sufficiency Consumption Space for Denmark and therefrom derive the new sufficiency sharing principle. Additionally, the Sufficiency

Consumption Space demands addressing luxury consumption, which I will do by identifying luxury goods and their embedded environmental impacts. In the next section I will explain my method for identifying these luxuries.

4.5 Distinguishing necessities from luxuries in consumption

After deriving the new sufficiency sharing principle for Denmark and assessing how all consumption goods in Denmark compare to that, I will then identify what environmentally harmful luxuries should be curbed to get Denmark back within the Planetary Boundaries. Specifically, I will propose using expenditure elasticities in the following.

Gough (2023) and several others (Steen-Olsen et al., 2023; Starr et al., 2023; Ivanova et al., 2015, 2020; Vita et al., 2019; Hertwich et al., 2009; Oswald et al., 2023) suggest a specific method to quantify a spectrum between necessary- and luxury goods. It entails calculating expenditure elasticities to identify most luxurious goods. I will do this for Danish annual household consumption with the use of national household budget survey data from Statistics Denmark[19]. Crucially, I will not use the elasticity analysis to derive basic human needs. This will be defined by Decent Living Standards in Schor (2023). The expenditure elasticities will only be used to identify the most luxurious and environmentally harmful consumption goods that should be curbed.

In traditional economic theory, ‘luxuries’ are formally defined as having an expenditure elasticity greater than 1, and the more above 1 the higher degree of luxury (Oswald et al., 2020; Gough, 2017). The intuition is simply that expenditures of a certain consumption category that rises relatively faster than the increase in total disposable income can be deemed luxuries. It indicates a relative prioritization towards certain luxury goods when income rises (Gough 2017). In this way, luxuries vary with income, contrary to necessities that are consumed more independently of income changes. Moreover, it follows from the definition that luxury goods are associated with higher incomes (Oswald et al., 2020). The formula for calculating expenditure elasticity is simply:

$$e_i = \frac{\frac{y_{i,t}}{y_{i,t-1}} - 1}{\frac{y_{total,t}}{y_{total,t-1}} - 1}$$

[19] Statistics Denmark FU01, FU05.

, where e_i is the elasticity for $good_i$, $\frac{y_{i,t}}{y_{i,t-1}} - 1$ is the annual percentage change in demand for good i, and $\frac{y_{total,t}}{y_{total,t-1}} - 1$ is the annual percentage change in total household expenditure.
Having quantified the luxury goods, then plotting the elasticities of each good against their corresponding environmental impact reveals a range of unsustainable luxury goods. This is where I will use bottom-up LCA to estimate the environmental impacts of as many relevant consumption goods of Denmark as possible[20]. These 'unsustainable luxury goods' are the ones that should be curbed and avoided to get back within the sufficiency consumption space (Baltruszewicz et al., 2023).

4.6 Planetary Boundary-based LCA

In this section I will explain the context of the sufficiency sharing principle that I will develop. In general, life cycle assessment enables quantifying the human-driven potential environmental impacts related to the entire life cycle of any human process, for example products and services (Bjørn et al., 2015). It is also a key aspect that LCA allows combining different environmental impact categories into a single indicator. I will apply this traditional LCA method in the analysis of household consumption in Denmark after deriving the sharing principle. However, traditional LCA can only be used to identify environmental efficiency improvements. Therefore, it is imperative to apply LCA methods that address the ecological space occupied by human activities and compare it to the absolute carrying capacities of the Earth (Bjørn et al., 2015).

Along this line, I will develop a sufficiency-based sharing principle that follows the type of LCA called "LCA-based Absolute Environmental Sustainability Assessment" (Bjørn et al., 2020). It has the overall purpose of evaluating whether any human activity can be considered environmentally sustainable in an absolute sense ("yes or no"). Fortunately, the development of the Planetary Boundaries framework (Rockström et al., 2009) has enabled comparing impacts of human activities against the Planetary Boundaries (Bjørn et al., 2015). This is denoted Planetary Boundary-based LCA (PB-LCA) as mentioned earlier (Ryberg, 2018). In a PB-LCA, you assign a proportionate share of Earth's biophysically limited carrying capacity to a product or activity at any scale. In other words, you give an activity a normative Share of the global Safe Operating Space (SoSOS) for humanity, which is then compared to the actual amount of environmental impact occurring from the activity (Hauschild et al., 2017).

[20] "Bottom-up" is in this regard understood as a process-based LCA that focuses on detailed modeling of individual processes to evaluate their environmental impacts.

The word 'absolute' is thereby used to highlight the comparison between actual impacts of an activity relative to its assigned share of the global carrying capacity (Bjørn et al., 2020). The scale of human activities in PB-LCAs can range a single product to a company or sector, or to a country or the entire global economy.[21]

A fundamental step within the PB-LCA is assigning a proportionate Share of the Safe Operating Space to the activity of analysis. To do this, sharing principles must be applied. A sharing principle can be defined as the process of assigning a proportionate share of a Safe Operating Space to an anthropogenic activity with the aim of ensuring that it stays within its assigned share of the planetary boundary (Bjørn et al., 2020; Birgisdottir et al., 2023). During this process, multiple sharing principles can be combined as one total sharing principle (Bai et al., 2024). If the actual environmental impacts of a given activity is below the assigned Share of Safe Operating Space (Allocated SoSOS) it can be considered absolute environmentally sustainable, and vice versa. The formal evaluation is simply:

$$\frac{Actual\ impact}{Allocated\ SoSOS} \leq 1 \rightarrow Absolute\ sustainable,$$

$$\frac{Actual\ impact}{Allocated\ SoSOS} > 1 \rightarrow Not\ absolute\ sustainable$$

This formula is denoted the Environmental Sustainability Ratio (Ryberg et al., 2021). Sharing principles are of decisive importance because the very choice of sharing principle strongly influences the conclusions and recommendations about the activity in consideration (Ryberg et al., 2020). Therefore, designing sharing principles should include ethical, political, economic, and social perspectives to answer the fundamental question: "What is to be shared among whom and how?" (Meyer et al., 2006).

Some of the main theories guiding the choice of sharing principles are theories of distributive justice (Perdomo Echenique et al., 2022). They serve to highlight the normative question of "based on what principle are things to be shared?" As outlined previously, I will adhere to the distributive justice principle of 'sufficiency', operationalized as the dual challenge of meeting basic needs for all within the Planetary Boundaries, and demanding the curtailment of excess luxury consumption.

[21] Crucially, in the PB-LCA, a given activity is not held up against the *global* safe operating space of the Planetary Boundaries because any single activity cannot claim the global aggregate safe operating space, except the entire Earth itself of course (Ryberg, 2018).

The use of sufficiency as the distributive principle in PB-LCA is backed up by several studies suggesting the use of sufficiency-based sharing principles (Ryberg et al., 2020; Heide et al., 2023). The distributive principle of equality ("the same for everyone") will play a key role in my sufficiency sharing principle, since every person will have the right to the same threshold levels of basic human needs, only differentiated by e.g. climatic conditions for housing, age for nutrition amount, and urbanization rate for mobility requirements. This is based on the argument that any sharing of a limited total of scarce resources should start with sharing among individual human beings (Lippert-Rasmussen, 2015). After satisfying threshold levels of basic needs, the remaining Safe Operating Space in Sufficiency Consumption Space of Denmark will be distributed equally per capita and can be used freely. My reason for doing that is the assumption that people should have the same initial right to use the remaining Safe Operating Space. You could also add inequality scenarios to this, which I will discuss later. Crucially, whether people *in reality* will consume the ecological space equally is another question.

The development and application of sufficiency-based sharing principles is very scarce in the literature. Some review studies mention 'sufficientarianism' but they do not find any existing sharing principles based on it and find it unfeasible to operationalize in their studies (Hjalsted et al., 2021; Ryberg et al., 2020). Furthermore, the most currently applied sharing principles in PB-LCA fail in satisfying basic human needs while not exceeding Planetary Boundaries (Hauschild et al., 2020). Hence, the need for new sufficiency-based sharing principles is evident. There are already a few existing sufficiency sharing principles. Although these are useful, I think that more sufficiency sharing principles can be developed. Therefore, before embarking on my analysis, I will do a brief literature review on what sufficiency-based sharing principles exist and how they are operationalized. This is important inspiration for developing a new one.

4.7 Review of sufficiency-based sharing principles

There are numerous PB-LCA review articles identifying all existing sharing principles, but none of them solely focus on sufficiency[22] (Bai et al., 2024; Bjørn et al., 2020; Perdomo Echenique et al., 2022; Häyhä et al., 2016; Hjalsted et al., 2021; Lucas et al., 2020; Ryberg et al., 2020; Ryberg et al., 2018; van den Berg et al., 2020)[23]. In addition, it is my argument that

[22] Also, in Appendix 5 I provide a brief argumentation why two of the most commonly used sharing principles in PB-LCA are not deemed fit for purpose. These are Final Consumption Expenditure and Gross Value Added.
[23] I have listed an overview of most existing sharing principles for PB-LCA in Table 9.4 in Appendix 4.

some of the most used sharing principles in PB-LCA – Final Consumption Expenditure (FCE) and Gross Value Added (GVA) – are not desirable to assess human wellbeing in absolute sustainability assessments. This argument is brought in Appendix 5.

In Table 4.1 below I have listed all the articles identified in my review that incorporate sharing principles based on human needs and sufficiency. In the most recent review, Bai et al. (2024) identify 13 articles that apply "basic needs and preferences" sharing principles. However, when investigating them, I see that they pool 'basic needs' and 'preferences' in the review. This is unfortunate since they represent two fundamentally different underlying theoretical views and assumptions. Therefore, after investigating all 13 articles, I revealed that only four of them can be rightfully ascribed using a 'basic needs' sharing principle. These are article 1.1-1.4 in the table.

Table 4.1: Identified articles involving sufficiency- and human needs sharing principles

	Article	**Method of incorporating basic needs and/or sufficiency**	**Short explanation** 
1	Bai et al. (2024)	Review article. Identifies 13 studies that include "basic needs and preferences" (elaborated below in 1.1-1.13).	"Basic needs and preferences" is described as "Shares are allocated such that fulfilment of human basic needs comes first, before distributing the rest of the resources to other non-basic needs."
1.1	European Environment Agency et al. (2020)	Include "needs" sharing principles like "equivalence between adults and children", "travel time to major cities", and "food nutrient adequacy"	"People have different resource needs due to e.g. age, household size or location. As a result, their right to resources could be differentiated according to population weighted by age".
1.2	Sandin et al. (2015)	Provides either same share, half the share of double the share (1, 0.5 or 2) to a given sector, based on its hypothetical contribution to fulfilling essential human needs such as clothes or shelter.	"It can be argued that market segments of high importance for essential human needs should have a right to a larger share of the allowed impact compared to their current share, and that less essential market segments, should have less of a right to cause impact". (Assumes how important a market segment is to fulfil human essential needs relative to the average market segment)

1.3	Chandrakumar et al. (2019)	Calorific Content	"Uses calories as a proxy to represent the fact that the primary purpose of agri-food production is to feed people".
1.4	Wolff et al. (2017)	Consumer base	"Uses calories as a proxy to represent the fact that the primary purpose of agri-food production is to feed people".
2	Heide et al. (2023)	Fulfilment of Human Needs (FHN)	Uses "closest-to-sustainable" countries and "sustainable consumption" of these countries to operationalize FHN.
3	Rao et al. (2018)	Using the Decent Living Standards	Defines a set of universal, irreducible and essential set of material conditions for achieving basic human wellbeing.
4	Millward-Hopkins et al. (2020)	Using the Decent Living Standards	Uses bottom-up model to estimate minimal threshold for final energy consumption required to provide decent material livings to global population. It uses DLS.
5	Rao et al. (2019)	Using the Decent Living Standards	Operationalizes DLS satisfiers into context-dependent material and energy requirements. Does not use it as sharing principle, but for estimating bottom-up the energy embodied in the material underpinnings of Decent Living Standards for India, Brazil, and South Africa.
6	Schor (2023)	Using the Decent Living Standards	Uses Millward-Hopkins et al. (2020) to estimate the environmental impacts of meeting DLS for global population.
7	Birgisdóttir et al. (2023)	Sufficiency	Operationalizes 'sufficiency' sharing principle as the share of final energy consumption needed for providing a given DLS dimension, e.g. housing (Millward-Hopkins et al., 2020).
8	Schlesier et al. (2024)	Using the Decent Living Standards and the Doughnut.	The first article to provide evidence whether global Safe and Just Operating Space can be achieved. Use the result to develop two new sufficiency-based sharing principles. One is across 9 key resources and the other is across 15 DLS dimensions.

Article 1.1 (European Environment Agency et al., 2020) includes 'basic needs' sharing principle in three ways. First, they use age-weighted population. However, this is not relevant for my operationalization of 'basic need' satisfiers. Second, they include 'travel time to major cities' as reflecting accessibility. This is more in line with my perspective on basic human needs, but it does not reflect energy- and material requirements. Third, they include nutrition levels across nations, which is in line with Doyal et al. (1991)'s Theory of Human Need and

Decent Living Standards (Millward-Hopkins et al., 2020). However, in sum, I do not see it as a coherent and comprehensive sufficiency sharing principle that answers the question of how a global population can have access to basic needs while living within the Planetary Boundaries and how to prioritize the remaining operating space.

Article 1.2 (Sandin et al., 2015) operationalizes 'basic needs' as giving either the same share, half the share of double the share (1, 0.5 or 2) to a given sector, based on its hypothetical contribution to fulfilling essential human needs, e.g. clothes or shelter. The right to cause the same share of impact as a consumption segment does today is argued by the idea that all market segments have the same obligation to reduce impacts, or that the clothing segment is an average sector in terms of fulfilling essential human needs or in terms of the proportion of its output that may be considered luxury goods (Sandin et al., 2015). As for the right to cause half the share of impact as today, the logic could be that a given consumption segment is larger than required for fulfilling essential human needs, and more so than the average sector. The assumption to have the right to cause twice the share of impact as today is based on the argument that a segment is more important for fulfilling essential human needs than the average market segment. In sum, there are relevant thoughts behind assigning half, equal or double impact share to a given sector here, but I find it too simplistic to be useful.

Article 1.3 (Chandrakumar et al., 2019) includes calorific content, reflecting that the primary purpose of the agri-food sector is to feed people. This is well in line with the metric for food in Decent Living Standards (Rao et al., 2018). Article 1.4 (Wolff et al., 2017) includes 'consumer base' in person.year.eq., arguing that it reflects the amount of people who are fully fed by a company's products.

Next, I find that Heide et al. (2023) in article 2 operationalizes 'sufficientarianism' as the fulfilment of human basic needs. They do it in two ways. First, they identify and use average consumption patterns in 11 identified "closest-to-sustainable" countries as the sufficiency allocation principle for climate change. More specifically, they do this by looking at data of Human Development Index, Ecological Footprint, and consumption-based emissions. They set up threshold value criteria to include "most sustainable countries", and they find that no countries meet the threshold criteria they set up, so they had to relax the criteria to identify "most sustainable countries". They then use the current household and government consumption expenditure shares of total consumption of those countries to identify average consumption patterns of what they determine to reflect human needs in 17 different consumption categories.

Second, they use the status-quo impact of Indonesia as a proxy for sustainable impact for land-system change, freshwater use and nitrogen cycling, the reason being that Indonesia was the only country with the available data in EXIOBASE[24], and I find that operationalization questionable. Also, I do not find it optimal to use currently ‘‘most sustainable countries’’ for the operationalization of sufficiency, since no country in the world currently provides sufficiency for all within Planetary Boundaries (O’Neill et al., 2018;Fanning et al., 2022). Furthermore, they operationalize the sharing principle differently across Planetary Boundaries. This is not necessarily unfortunate per se, but I find it preferable to develop a coherent operationalization of sufficiency across all Planetary Boundaries.

Finally, the article does not address all planetary boundaries but only climate change, nitrogen, freshwater and land-use change. These are of course very important boundaries, but I will try to include all the 9 Planetary Boundaries to be fully systemic in my assessment. Concluding, Heide et al. (2023) excels in being one of the first studies to try developing a sufficiency sharing principle, and it was a key inspiration for me to follow the same line of research effort. So, the limitations of the study have served as inspiration to try contributing to this research area.

Articles 3-6 all include a quantitative operationalization of requirements for meeting Decent Living Standards, which is conceptually based on the Theory of Human Needs (Doyal et al., 1991). They do not operationalize a sufficiency sharing principle, but the studies are highly relevant because they can be a part of my development of a sharing principle. In article 5 (Rao et al., 2019) they estimate bottom-up the energy embodied in the material underpinnings of Decent Living Standards for India, Brazil, and South Africa, which also builds upon their previous study. Recently, article 6 (Schor, 2023) went further and used Millward-Hopkins et al. (2020) to estimate the environmental impacts of meeting the Decent Living Standards for the global population. This is very useful because I will use it as a ‘floor of human needs’ in my analysis. This will be further elaborated.

Article 7 (Birgisdóttir et al., 2023) includes the Decent Living Standards from Millward-Hopkins et al. (2020) by using the share of final energy consumption needed for providing a given DLS dimension as the sharing principle at sector level, for example housing. They argue that the shares of minimum energy required for decent living across these categories can be used to allocate sufficiency-based sectoral shares to the housing sector of a given

[24] EXIOBASE is a detailed multi-regional input-output database used for environmental and economic assessments, providing data on the environmental impacts and resource use across global supply chains.

country, e.g. Denmark. I find this method useful, since it is based on Millward-Hopkins et al. (2020), which is based on a coherent theory of basic human needs. It is also easy to apply because the sharing principle is already calculated in Millward-Hopkins et al. (2020). The limitations of this sharing principle could be that it uses final energy consumption as basis for the sharing principle and does not directly incorporate all the materials and emissions inherent to meet the basic human needs. This is what Schor (2023) addresses in his study, based on Millward-Hopkins et al. (2020). All in all, Birgisdóttir et al. (2023) presents a simple and relevant sharing principle for the overall DLS dimensions, but more detailed sharing principles are needed that can go down to a product-level. For example, the DLS dimension 'housing' consists of many different consumption goods that we must make decisions on for reaching sustainable development, and Birgisdóttir et al. (2023) does not provide a sharing principle at this level of granularity. However, it has been inspirational for my thesis as well.

Finally, in the most recent article 8, Schlesier et al. (2024) derive two sufficiency-based sharing principles from their analysis of the technical possibility of getting within a safe and just operating space for a global population in 2050[25]. Notably, their study is the first to investigate whether it is theoretically feasible to meet Decent Living Standards for all people in 2050 within all the Planetary Boundaries. Their first sufficiency sharing principle is shown as ideal "sufficiency-allocation" to 9 critical resource segments: Chemicals, metals, minerals, energy, textile, animal-based agriculture, plant-based agriculture, wood, and water. Therefore, this is highly relevant on this overall resource level for sectoral prioritization. This allocation key is derived by allocating impact shares of identified material producing processes of the Safe and Just Operating Space scenario to key resource segments. The second sufficiency sharing principle is showing the allocation of the Safe and Just Operating Space across the 11 Planetary Boundary translated segments to 15 Decent Living Standards dimensions.

Overall, the sharing principle of Schlesier et al. (2024) is indeed similar to the approach I have taken in my thesis. Furthermore, it is an advantage in Schlesier et al. (2024) compared to Schor (2023) that it incorporates technological development in its scenario of meeting Decent Living Standards for all in 2050. In that aspect it approaches a more ideal operationalization of future sufficiency living than Schor (2023) who does not incorporate that. Finally, a limitation of Schlesier et al. (2023) is that they do not include technological development in their background system of their scenarios. However, this is not done in Schor (2023) either, which I will apply. An advantage of using Schor (2023) in my analysis is that he

[25] I have listed the two sharing principles in Appendix 6.

has constructed a fully parameterized model so that I can pull out the impact results for meeting the Decent Living Standards in Denmark, which is not possible in Schlesier et al. (2024). This is needed because my focus of analysis is Denmark.

In sum, Schlesier et al. (2024) have - arguably - developed the most coherent and elaborated sufficiency sharing principle to date, and the theoretical foundation very aligned to my thesis. One aspect, where I have chosen a different focus and try to go further is to investigate how consumption in the remaining operating space between the Planetary Boundaries and meeting human needs should be allocated in theory. Thus, I try to develop a sufficiency sharing principle for all Danish consumption goods that do not constitute basic needs. This is a key part of my possible contribution.

Summing up, from Table 4.1 above I argue that five unique sharing principles currently exist that operationalize 'human basic needs' and/or 'sufficiency'[26]. These are listed in Table 4.2:

Table 4.2: Existing sharing principles for PB-LCA based upon human basic needs and/or sufficiency

Article	Method of incorporating human basic needs and/or sufficiency	Explanation
(Sandin et al., 2015)	Provides either same share, half the share of double the share (1, 0.5 or 2) to a given sector. It is based on its hypothetical contribution to fulfilling essential human needs such as clothes or shelter.	"It can be argued that market segments of high importance for essential human needs should have a right to a larger share of the allowed impact compared to their current share, and that less essential market segments, should have less of a right to cause impact" (Sandin et al., 2015). Assumes how important a market segment is to fulfil human essential needs relative to the average market segment.
(Heide et al., 2023)	Fulfilment of Human Needs (FHN)	Uses "closest-to-sustainable" countries and "sustainable consumption" of these countries to operationalize FHN.
(Birgisdóttir et al., 2023)	Sufficiency	Operationalizes 'sufficiency' sharing principle as the share of final energy consumption needed for providing a given DLS dimension, e.g. housing (Millward-Hopkins et al., 2020.

[26] Based on the approach of Birgisdóttir et al. (2023), however, I would argue that a sixth sufficiency sharing principle exists. You can apply the same operationalization for Millward-Hopkins et al. (2022) as they did in Millward-Hopkins et al. (2020 to develop a sharing principle, the only difference being the inequality considered in the former. It is arguably highly relevant to incorporate ideal inequality scenarios since the vision of complete equality per global capita is likely too unrealistic in the near future.

Schlesier et al. (2024)	Using the Decent Living Standards and the Doughnut.	The first article to provide evidence whether global Safe and Just Operating Space can be achieved. Use the result to develop a new sufficiency-based sharing principle across 9 key resources
Schlesier et al. (2024)	Using the Decent Living Standards and the Doughnut.	The same as above but across 15 DLS dimensions.

To my knowledge, I have hereby provided a fully updated overview of existing sufficiency-based sharing principles that I use as inspiration and context for developing a new one. This is the answer to my research sub question 3 and to the entire theory section. In the next section, I will embark on the analysis.

5. Analysis

My analysis will consist of three parts that answer sub questions 4-6:

SQ 4	How can a new sufficiency-based sharing principle be developed that reflects staying within all Planetary Boundaries and satisfying basic needs?	Analysis Section 6.1
SQ 5	What is the environmental impact of Danish household consumption? And how does it compare to the sufficiency sharing principle?	Analysis Section 6.2
SQ 6	What consumption goods should be focused on when analyzing the degree of luxury and environmental impacts of consumption?	Analysis Section 6.3

In short this will be answered by:

SQ 4	The sufficiency sharing principle involves prioritizing a share of safe operating space to meeting Decent Living Standards for all people. Then, the remaining share of safe operating space can be used for any consumption purpose chosen by the individual.	Analysis Section 5.1
SQ 5	Conduct a bottom-up LCA of the environmental impact potentials of all consumption goods of Danish annual household consumption	Analysis Section 5.2
SQ 6	Combine expenditure elasticities and LCA from SQ 5 to reveal goods with highest degree of luxury and environmental impact, using average annual consumption levels per good	Analysis Section 5.3

Answering sub question 4 will allow me to propose a sufficiency sharing principle on a 'per capita' level for Denmark that can be used for PB-LCA. Afterwards, I will make a bottom-up LCA of annual Danish household consumption with as many different consumption goods as possible. This will shed light on the relation between the new sufficiency sharing principle and the actual consumption goods in Denmark, answering sub question 5.

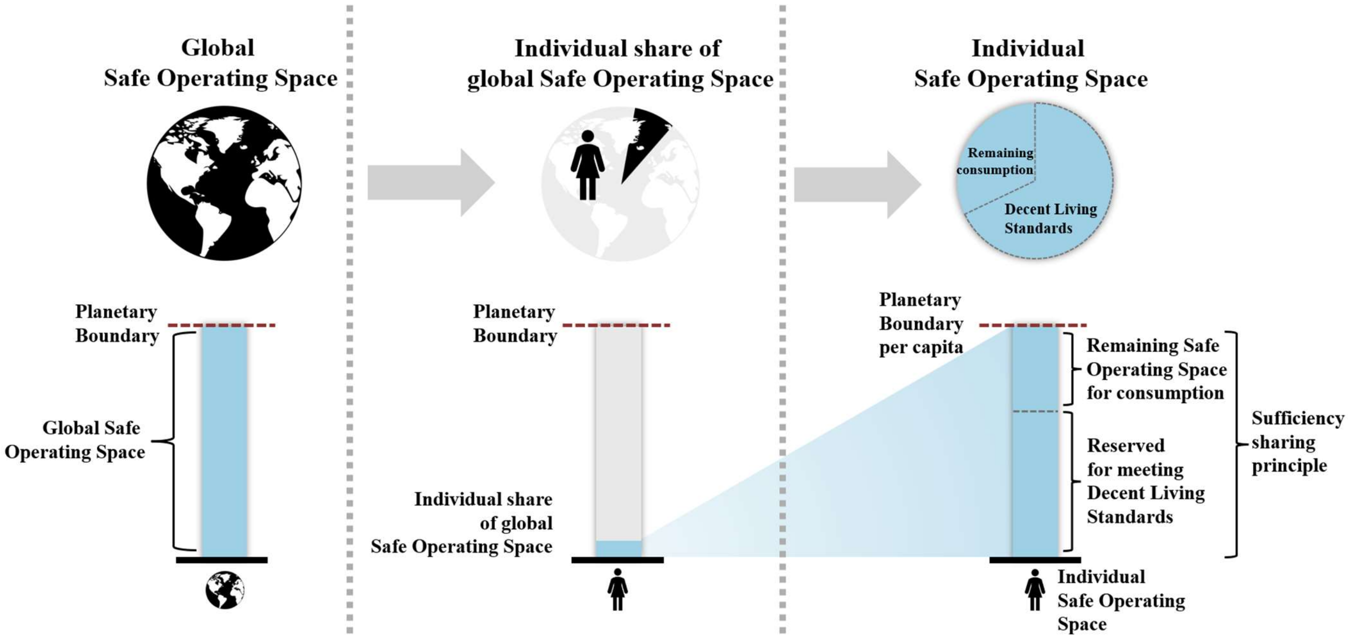
Finally, for answering sub question 6 I will suggest what consumption goods should be addressed when designing policies and interventions to decrease environmental impacts of Danish household consumption to get back within Planetary Boundaries. Investigating concrete policy recommendations and interventions are beyond the scope of this thesis though. I will simply suggest addressing those goods that combined have the highest degree of luxury and environmental impact.

5.1 Deriving a new sufficiency sharing principle

In this section I will derive the sufficiency-based sharing principle on a 'per capita' level for Denmark, answering sub question 4. The derivation process is illustrated in Figure 4.4 below and consists of three main steps.

First, the global Safe Operating Space is defined by the Planetary Boundaries. Second, the global Safe Operating Space is divided equally among all people in the world to define an individual share of the global Safe Operating Space. Third, a share of the individual Safe Operating Space is then strictly reserved to secure satisfying Decent Living Standards. Finally, the remaining amount of individual Safe Operating Space – after having reserved ecological space for meeting Decent Living Standards - is then free for any consumption purpose by the individual. In sum, this is my proposal of a new sufficiency-based sharing principle on a 'per capita' level.

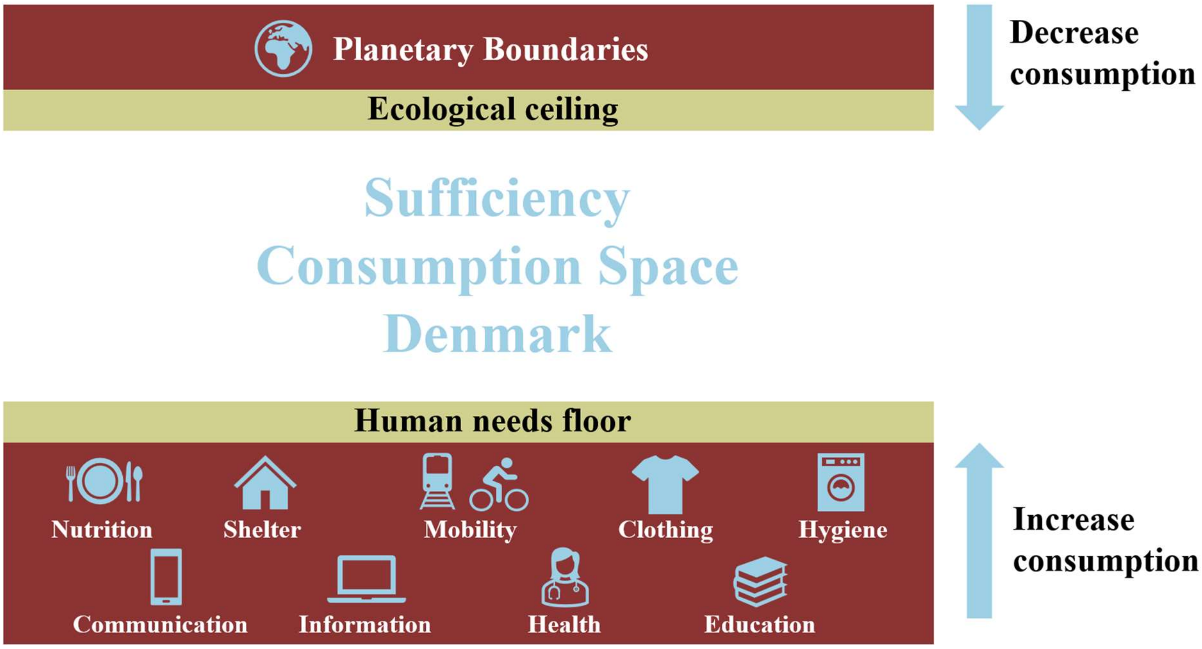
Figure 5.1: Deriving a new sufficiency-based sharing principle



Source: Own illustration

The derivation of the sufficiency-based sharing principle in Figure 5.1 follows the vision of a Sufficiency Consumption Space for Denmark, as outlined in the theory section. I have visualized this in more detail in Figure 5.2 below:

Figure 5.2: Sufficiency Space for Denmark



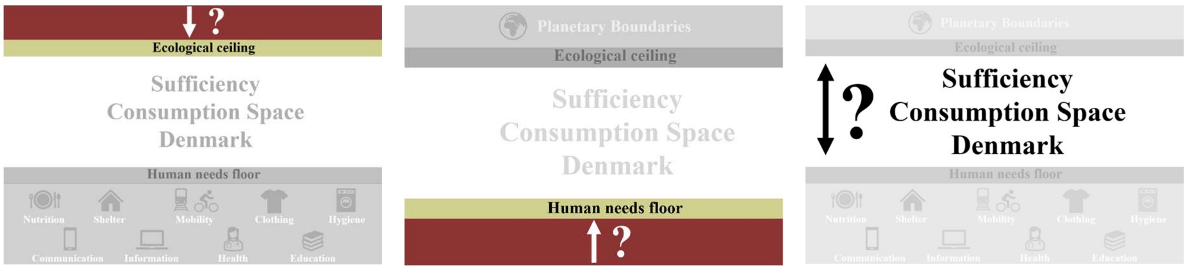
Source: Own illustration. Inspired by Akenji et al. (2021).

By looking at the sharing principle in Figure 5.1 and the Sufficiency Consumption Space of Denmark in Figure 5.2, it is also clear that addressing excess overconsumption is not a direct part of my sufficiency sharing principle. However, when applying my sufficiency principle in PB-LCA concerning consumption, it will likely become clear that current consumption patterns of Denmark are not absolute sustainable, thus, demanding excess consumption to be curbed. This is illustrated in the Sufficiency Consumption Space in Figure 5.2, where excess consumption should be curbed *as a consequence* of people not having an absolute sustainable lifestyle in relation to Planetary Boundaries.

For that reason, after deriving the new sufficiency sharing principle I will continue the analysis with analysing the actual household consumption of Denmark and finally analyse what consumption goods could be curbed to get back within the Planetary Boundaries. But first, I will derive the sharing principle. The three steps in Figure 5.1 for deriving the sharing principle are described in more in detail in the following Table 5.1:

Table 5.1: 3 steps of Defining Sufficiency Consumption Space per person for Denmark

Step 1: Define the ecological ceiling	**Step 2:** Define the human needs floor	**Step 3:** Define the remaining Safe Operating Space per capita



Step 1: Define the ecological ceiling	**Step 2:** Define the human needs floor	**Step 3:** Define the remaining Safe Operating Space per capita
Use Sanye et al. (2023) - or a more recent update hereof - to establish the ecological ceiling per global capita by using the Planetary Boundary-based carrying capacities. This defines the annual Safe Operating Space per global capita equally.	Use the Decent Living Standards for Denmark from Schor (2023) to estimate the environmental impacts of meeting Decent Living Standards per Danish capita. This is the human needs floor that must be met. Meeting these Decent Living Standards must have priority before assigning the remaining operating space to all consumption purposes (step 3).	Subtract the environmental impacts of meeting Decent Living Standards per capita of Denmark (step 2) from the global Safe Operating Space per capita (step 1). The result is then the remaining Sufficiency Consumption Space per capita of Denmark that can be used for any consumption purpose by the individual. Step 1 and 2 secures staying beneath ecological ceiling and above human needs floor.

Therefore, I will go through each step to quantify the sufficiency sharing principle.

Step 1: Define the ecological ceiling, per person

For defining the 'ecological ceiling' I will use the Planetary Boundaries framework, translated into 16 Planetary Boundary-based life cycle impact assessment (LCIA) indicators. These 16 impact indicators are from the Environmental Footprint LCIA method developed by the European Commission (Sala et al., 2020; Sanye et al., 2023) and their values are shown in the fourth column in Table 5.2 below. Note that the values are 'per year'. In a metaphor, the Planetary Boundaries set "the size of the global cake" that can be consumed, which is the global Safe Operating Space per year. By dividing the global Safe Operating Space by the global population of 2023, you get the Safe Operating Space per global capita – assuming all people globally have the same human right to claim a share of the global ecological space for achieving "a standard of living adequate for the health and well-being of himself" (United Nations, 1948) [27]. This is estimated in the fifth column[28], which is then the Safe Operating Space per year for any person in Denmark as well. This leads to step 2.

Table 5.2: Planetary Boundaries, total and per global capita, 2023

ECOLOGICAL CEILING				
Impact category	**Indicator**	**Unit**	**Planetary Boundary**	**Planetary Boundary per global capita, 2023**
Acidification	Accumulated exceedance	Molc H+ eq	1,000,000,000,000	**124**
Climate change	Radiative forcing (GWP100)	Kg CO2e	6,810,000,000,000	**846**
Ecotoxicity, freshwater	Comparative Toxic Unit for humans	CTUe	131,000,000,000,000	**16283**
Eutrophication, marine	Fraction of nutrients (P) reaching freshwater end compartment	Kg P eq	5,810,000,000	**0.72**
Eutrophication, freshwater	Fraction of nutrients (N) reaching marine end	Kg N eq	201,000,000,000	**25.0**
Eutrophication, terrestrial	Accumulated exceedance	Molc N eq	6,110,000,000,000	**759**
Human toxicity, cancer	Comparative Toxic Unit for humans	CTUh	962,000	**0.00012**
Human toxicity, non-cancer	Comparative Toxic Unit for humans	CTUh	4,100,000	**0.00051**
Ionising radiation, human health	Human exposure efficiency relative to U235	kBq U235 eq	527,000,000,000,000	**65504**
Land use	Soil quality index	Pt	3,980,000,000,000,000	**494698**
Ozone depletion	Ozone Depletion Potential	Kg CFC-11 eq	539,000,000	**0.067**
Particulate matter	Impact on human health	Disease incidence	516,000	**0.000064**
Photochemical ozone formation, human health	Tropospheric ozone concentration	Kg NMVOC	407,000,000,000	**50.6**
Resource use, fossil	Abiotic resource depletion, fossil	MJ	224,000,000,000,000	**27842**
Resource use, minerals and metals	Abiotic resource depletion, ADP ultimate reserve	Kg Sb eq	219,000,000	**0.027**
Water use	User deprication potential	m3 world eq	182,000,000,000,000	**22622**

Source: 'Planetary boundary' from Sanye et al. (2023); Global population 2023 from UN Population Division
Note: Global population 2023: 8,045,311,448.

Step 2: Define the human needs floor, per person

For defining the satisfaction of a 'human needs floor' I will use the Decent Living Standards LCA model of Schor (2023). Table 5.3 depicts the 9 dimensions of Decent Living Standards

[27] as mentioned in the pre-analytic vision.
[28] Assuming an anthropogenic ethical standpoint, reflecting only humans can claim shares of the ecological operating space.

from Schor's LCA model (2023). These are the specific material- and energy requirements for meeting Decent Living Standards in Denmark per person with the current provisioning systems.

Table 5.3: Decent Living Standards for Denmark

HUMAN NEEDS FLOOR												
DLS dimension (1-3)	**Nutrition**				**Shelter**					**Hygiene**		
DLS sub dimension	**Food**	**Food waste**	**Cold storage**	**Preparation**	**Dwelling**	**Final energy use**	**Thermal comfort**	**Illumination**	**Comfort**	**Water**		
Need satisfier characteristics	Calories, proteins, micro-nutrients	At consumer	Refridgerator (100L)	Stove (50% of total food is heated)	sufficient living space	Electricity use	Heating equipment	Lighting, LED	Furniture	Water supply	Water heating	
Amount	2500	20	120	6	69	954	18,7-61,2	30	1000	50	20	
Unit	kcal/pers/day	%	kWh/pers/yr	MJ/kg food	m2/dw/yr	MJ/pers/yr	MJ/pers/yr	LEDs/dw	kg/dw	L/pers/day	L/pers/day	
DLS dimension (4-9)	**Clothing**		**Health**		**Education**		**Information access**	**Communication access**	**Mobility**			
DLS sub dimension	**Clothing**	**Laundry**	**Healthcare facility**	**Healthcare operations**	**Education facility**	**Educational activities**	**Information access**	**Communication access**	**Air transport**	**Road transport**	**Road transport**	**Road transport**
Need satisfier characteristics	Obtained clothes	Washing machine	Sufficient space	Final demand for healthcare operations	Equipped schools	Final demand of educational activities	Computer/internet access	Telephone/smartphone	Flights	Bicycle	Car	Bus and train
Amount	3.03	1	1.6	759	10	649	1	1	1067	1251	516-2383	1033-4766
Unit	kg/pers/yr	washing machine/dw	m2/patient/yr	EUR/patient/yr	m2/pupil/yr	EUR/pupil/year	computer/dw	phone/pers	km/pers/yr	km/pers/yr	pkm/yr	pkm/yr

Next, the advantage of Schor's (2023) LCA model is that it is possible to calculate the environmental impacts of meeting the Decent Living Standards per person of Denmark[29]. These results will be shown in Table 5.4 in a moment. Now that I have established the ecological ceiling and human needs floor, it is possible to define the remaining Safe Operating Space per person of Denmark in step 3.

Step 3: Define the remaining Safe Operating Space per person

The final step is to calculate the remaining Safe Operating Space per capita that is left beneath the ecological ceiling and after setting aside environmental operating space to meet the Decent

[29] This has been modelled by Schor (2023) in collaboration Joel Millward-Hopkins and is based on the latter person's previous study (Millward-Hopkins et al., 2020). Additional parameters relation to the human needs floor of Schor (2023) are presented in appendix X.

Living Standards. This is simply done by subtracting the environmental impacts of meeting Decent Living Standards per person of Denmark (step 2) from the Planetary Boundaries per person of Denmark (step 1). As outlined in the theory section about 'sufficiency', the remaining Safe Operating Space per person can be used for any consumption purposes because the ecological space for meeting Decent Living Standards have already been reserved and it is secured that the ceiling will not be transgressed. The subtraction yields the remaining Safe Operating Space per person of Denmark shown in Table 5.4 below.

Combining Table 5.2 and Table 5.3 essentially constitutes the two parts of my new sufficiency sharing principle, as shown in Table 5.4. The first part is the share of the individual Safe Operating Space that must be reserved to fulfil Decent Living Standards in Denmark. The second part is simply the remaining share of the individual Safe Operating Space that can be used for any consumption purpose chosen by the individual. Together, they form the new sufficiency-based sharing principle.

Figure 5.4: The sufficiency-based sharing principle

Planetary boundary-	Acidification	Climate change	Ecotoxicity, freshwater	Particulate matter	Eutrophication, marine	Eutrophication, freshwater	Eutrophication, terrestrial	Human toxicity, cancer
Unit	*mol H+ eq*	*kg CO2e*	*CTUe*	*disease incidence*	*kg N eq*	*kg P eq*	*molc N eq*	*CTUh*
Value	1.00E+12	6.81E+12	1.31E+14	5.16E+05	2.01E+11	5.81E+09	6.11E+12	9.62E+05
Boundary per capita	124.3	846.5	16282.8	0.000064	25.0	0.7	759.4	0.00012
Planetary boundary-adapted LCIA (9-16):	**Human toxicity, non-cancer**	**Ionising radiation, human health**	**Land use**	**Ozone Depletion**	**Photochemical ozone formation, human health**	**Ressource use, fossils**	**Ressource use, minerals and metals**	**Water use**
Unit	*CTUh*	*kBq U235 eq*	*Pt*	*kg CFC-11eq*	*kg NMVOC*	*MJ*	*kg Sb eq*	*m3 water eq*
Value	4.10E+06	5.27E+14	3.98E+15	5.39E+08	4.07E+11	2.24E+14	2.19E+08	1.82E+14
Boundary per capita	0.00051	65504.0	494698.1	0.1	50.6	27842.3	0.027	22621.9

ECOLOGICAL CEILING

Sufficiency Consumption Space

(Remaining Safe Operating Space per person in Denmark)

Sufficiency sharing principle

Impact category (1-8):	Acidification	Climate change	Ecotoxicity, freshwater	Particulate matter	Eutrophication, freshwater	Eutrophication, marine	Eutrophication, terrestrial	Human toxicity, cancer
Unit	mol H+ eq	kg CO2 eq	CTUe	disease inc.	kg P eq	kg N eq	mol N eq	CTUh
Value	104.9	-1411	-59557	0	14.9	0.044	684.22	0.00012
Impact category (9-16):	**Human toxicity, non-cancer**	**Ionising radiation**	**Land use**	**Ozone depletion**	**Photochemical ozone formation**	**Resource use, fossils**	**Resource use, minerals and metals**	**Water use**
Unit	CTUh	kBq U-235 eq	Pt	kg CFC11 eq	kg NMVOC eq	MJ	kg Sb eq	m3 depriv.
Value	0.00038	65332	223988	0.066	40.2	6406	-0.066	15527

IMPACTS FROM MEETING HUMAN NEEDS FLOOR

Impact category (1-8):	Acidification	Climate change	Ecotoxicity, freshwater	Particulate matter	Eutrophication, marine	Eutrophication, freshwater	Eutrophication, terrestrial	Human toxicity, cancer
Unit	mol H+ eq	kg CO2 eq	CTUe	disease inc.	kg N eq	kg P eq	mol N eq	CTUh
Value	19.38	2257	75840	0.00018	10.08	0.68	75.23	0.0000046
Impact category (9-16):	**Human toxicity, non-cancer**	**Ionising radiation**	**Land use**	**Ozone depletion**	**Photochemical ozone formation**	**Resource use, fossils**	**Resource use, minerals and metals**	**Water use**
Unit	CTUh	kBq U-235 eq	Pt	kg CFC11 eq	kg NMVOC eq	MJ	kg Sb eq	m3 depriv.
Value	0.00013	172.4	270711	0.00055	10.38	21435.81	0.093	7095

Now that the sufficiency-based sharing principle is derived in Figure 5.4, one might ask what makes it *sufficiency-based*? To reiterate this, I deem the new sharing principle theoretically "sufficiency-based" because it satisfies the definitions outlined in the theory section. That is, my sharing principle is *sufficiency-based* because it fulfils the following:

- ✓ Bringing all people up to thresholds where basic needs are satisfied (Doyal et al., 1991)
- ✓ Respecting all the Planetary Boundaries

- ✓ A sustainable and fair consumption space between a ‘floor of necessity’ and a ‘ceiling of excess’ (Gough, 2023).
- ✓ Defining a human needs floor and an ecological ceiling, forming a sustainable consumption space in which people can live freely and environmentally sustainable (Fuchs et al., 2021).
- ✓ Respecting the UN Declaration of human rights to ”a standard of living adequate for the health and wellbeing of himself, including food, clothing, housing and medical care and necessary social services” (United Nations, 1948).
- ✓ Prioritizing need-based ‘sufficiency consumption (Doyal et al., 2017).
- ✓ Distributing Earth’s resources more equally (Doyal et al., 1991; Akenji et al., 2021; Daly, 2018).
- ✓ Avoiding demand for materials, energy, land, and water while delivering human well-being for all within Planetary Boundaries (Creutzig et al., 2022).
- ✓ Enabling PB-LCA that can shed light on excess overconsumption (Gough, 2017).

However, my new sharing principle for PB-LCA is only addressing the normative allocated Share of the Safe Operating space per person in Denmark that enters the denominator or the PB-LCA equation:

$$\frac{Actual\ impact}{\boldsymbol{Allocated\ SoSOS}} \leq 1 \rightarrow Absolute\ sustainable$$

Assessing the actual impact of a person’s consumption is also needed to deem it absolute sustainable or not. Therefore, in the next section I will shed light on actual Danish household consumption and compare it to the sufficiency sharing principle. Since the sufficiency sharing principle is reflecting ‘total annual Safe Operating Space per person’ it would be natural to assess the ‘actual annual impact from consumption of one person’ to evaluate on the absolute sustainability equation above. However, my focus will be slightly different since it is not easily defined what ‘annual consumption of one person’ is. Thus, I will conduct a bottom-up LCA of as many household consumption goods in Denmark, and then one can look at any combination of consuming these goods in different amounts and compare it to the sufficiency sharing principle.

Depending on what type of consumption you investigate, you can argue that it should be compared to either the ‘remaining Safe Operating Space per person’, or to the part that 'meets Decent Living Standards', or to the entire Safe Operating Space per person. This depends on whether you assess goods that satisfy basic needs, goods that do not, or goods that do both[30]. In the next section, I will calculate the environmental impacts of Danish households' annual consumption by process-based LCA and compare it to the entire Safe Operating Space per person[31].

5.2 LCA of Danish household consumption

I will do the LCA for as many consumption goods as possible, so I have identified as much Danish household consumption activity data as possible. The functional unit of the entire LCA will then be the "total annual Danish household consumption of goods and services"[32]. However, I will not only show the results in totals, but also per unit of the consumption type. For example, I will show the total environmental impact from all annual meat consumption in Denmark but also per kg meat consumed. I have used the most recent consumption activity data available for all goods. For the life cycle impact assessment I will employ the Environmental Footprint 3.1 method, developed by the European Commission because it aligns with my developed sufficiency sharing principle[33][34].

As a first step, I have compiled an inventory of all available data on Danish annual household consumption in physical quantities. The data sources are stated in Table 9.7 in Appendix 7.[35] I have sought to find detailed data for the environmentally most important consumption categories: Food, Housing (incl. energy use), and Mobility (The Danish Energy Agency, 2024; UNEP, 2024). In total, I could find activity data for 625 consumption goods.

Second, the EU LCA platform provides a Consumption Footprint for all EU countries, which is a fully bottom-up regionalized LCA of the most representative household goods. I have used the data for Denmark[36][37]. Next, for all the other consumption data, the best matching

[30] This is just my simple suggestion. It can easily be discussed.
[31] Because I include goods that can be argued to partly satisfy basic needs.
[32] However, I am aware that there are thousands of more consumption goods available on the market. I have only included as many as I could.
[33] specifically the EU Joint Research Centre and Drectorate-General for the Environment. This method is a part of EU's effort to standardize LCA methods of products and organizations. See: https://tinyurl.com/EF-Platform
[34] Developed by Sala et al. (2020)
[35] Note that the data cannot be summed, since there are overlapping consumption items in the different sources
[36] I have included all these for Denmark, amounting to 142 household consumption goods. For all these goods it was possible to download the impact results for Denmark 2021 directly from the EUs LCA platform
[37] https://tinyurl.com/consfoot. Notably, the impact results are regionalized for Denmark.

unit processes were identified in the Ecoinvent 3.10 database in Simapro 9.6, which can then be multiplied with the activity data to yield total annual impacts[38].

5.2.1 Investigating total impacts

The total annual impacts per person in Denmark is simply derived as the total annual impact of a consumption good divided by the population of Denmark in the year of the activity. Since there are 625 different consumption goods with 16 impact category values, I will not show the total results here[39]. Thus, to bring an indication of the results Table 5.11 shows the top 10 consumption goods sorted by single weighted score (left) and climate change (right).

Table 5.11: Top 10 consumption goods with highest overall environmental score and highest climate change impact, per person

	Single weighted score (highest)	Value, milli Pts.	Climate change (highest)	Value, kg CO2e
1	Beef meat	196.6	Beef meat	1289.2
2	Bovine meat	112.3	Gasoline passenger cars	1221.8
3	Milk (excl. butter)	109.6	Pig meat	570.1
4	Gasoline passenger cars	95.5	Single family houses (before 1945)	551.8
5	Heat use, Single Family House	79.8	Cheese	535.9
6	Pig meat	79.4	Heat use, Single Family Houses	500.0
7	Cheese	64.6	Diesel passenger cars	472.8
8	Diesel passenger cars	41.0	Single family house (1945-1969)	465.7
9	Washing machine	40.6	Milk (excl. butter)	461.9
10	Single Family House (before 1945)	39.9	Single family house (1970-1989)	433.0

[38] Multiplying the consumption activity data with corresponding unit processes in Simapro yields a LCIA of the Danish annual household consumption across the 16 impact categories of Environmental Footprint 3.1. For transparency, these 16 impact categories are shown in Appendix 8. All the consumption inventory data is stated in the following units: kg, litres, m^3, pieces, pkm, TJ, and guestnight. The unit "pieces" is for any non-separable consumption unit, e.g. 1 Iphone.
[39] The total impact of all 625 consumption goods is listed in Appendix 9. This is in totals, not per capita.

Overall, Table 5.11 reveals that animal-based food, internal combustion engine passenger cars, housing, and heat use are causing the most environmental impact in Denmark, both in terms of overall environmental impact and climate change in isolation.[40] This aligns well with the Danish Energy Agency (2024) and UNEP (2024) highlighting Food, Housing, and Mobility as the most impacting consumption categories from an environmental perspective.

Next, to compare the impact results of the 625 consumption goods in Denmark to the new sufficiency-based sharing principle, I will show a fictitious example of a basket of five consumption goods and compare it to the share of Safe Operating Space per person. As mentioned, whether to compare the basket of consumption goods to the entire individual share of global Safe Operating Space or only to the remaining Safe Operating Space per person can be discussed. However, I leave this question aside for now and compare the basket of five goods to the entire individual Safe Operating Space, assuming the goods may help satisfying both basic needs and non-necessary consumption purposes. I have randomly chosen five representative consumption goods and quantified it with average annual consumption levels. Summing the environmental impacts of these five goods and dividing them by the individual share of global Safe Operating Space reveals whether this simple basket of five consumption goods can be considered absolute environmentally sustainable or not. The purpose of doing this is to make it more tangible and transparent what the individual share of global Safe Operating Space corresponds to in current Danish consumption patterns.[41] The results are shown in Table 5.12 below.

[40] Note that Heat use is placed higher than Single Family House on the overall environmental top 10, which is contra intuitive. This is likely because they are from two different data sources. 'Single Family House' is from EU Consumption Footprint 2021 and 'Heat use' is modeled by me with use of detailed energy data from The Danish Energy Agency, 2022.

[41] It would be relevant to define stereotype lifestyles and investigate the impact of these. This is however beyond the scope of my thesis.

Table 5.12: Basket of goods compared to individual Safe Operating Space

Colour grading: **Absolute sustainable** | **Not absolute sustainable**

(1/2)	Unit of consumption	Amount	Single weighted score	Acidification	Climate change	Ecotoxicity, freshwater	Particulate matter	Eutro-phication, marine	Eutro-phication, freshwater	Eutro-phication, terrestrial	Human toxicity, cancer
			points	mol H+ eq	kg CO2e	CTUe	disease incidence	kg N eq	kg P eq	molc N eq	CTUh
Volkswagen Golf	*pkm*	*7,995*	0.357	10.9	3142	25295	0.00017	2.59	0.549	27.8	3.11E-05
Meat consumption (represented as pigmeat)	*kg*	*52*	0.076	8.6	546	47449	0.000071	2.90	0.050	26.26	2.69E-07
Cheese	*kg*	*10*	0.022	3.6	185	2616	0.000028	1.23	0.015	12.20	7.70E-08
Single Family Housing (1970-1989 house)	*dwelling use of avg. Person/yr*	*1*	0.420	14.0	5822	8002	0.00024	2.74	0.103	32.18	2.04E-06
Coffee	*kg*	*8.6*	0.010	0.97	57.83634	1797.71	0.00	0.65	0.01	4.13	0.00
Total, basket of 5 goods			0.885	38	9753	85159	0	10	1	103	0
Individual share of safe operating space			1.809	124.3	846.5	16283	0.000064	24.98	0.72	759.45	0.00012
Absolute environmental sustainability factor			0.5	0.3	11.5	5.2	8.1	0.4	1.01	0.1	0.3

(2/2)	Unit of consumption	Amount	Human toxicity, non-cancer	Ionising radiation	Land use	Ozone depletion	Photo-chemical ozone formation	Resource use, fossils	Resource use, minerals and metals	Water use
			CTUh	kBq U235 eq	Pt	kg CFC-11eq	kg NMVOC	MJ	kg Sb eq	m3 water eq
Volkswagen Golf	*pkm*	*7994.6*	0.000030	93.78	17190	0.000094	16.0	69487	0.03889	338
Meat consumption (represented as pigmeat)	*kg*	*52*	0.000011	8.38	24865	0.000720	1.14	2907	0.00030	366
Cheese	*kg*	*10*	0.000004	3.07	4005	0.000098	0.31	1189	0.00014	13.7
Single Family Housing (1970-1989 house)	*dwelling use of avg. Person/yr*	*1*	0.000039	77.4	98608	0.000605	8.66	115359	0.01	705
Coffee	*kg*	*8.6*	0.00	0.0000	3.74E+03	0.000	0.23	3.05E+02	0.00	53
Total, basket of 5 goods			0	183	148407	0	26	189247	0	1476
Individual share of safe operating space			0.00051	65504	494698	0.067	5.06E+01	27842	0.027	22622
Absolute environmental sustainability factor			0.2	0.003	0.3	0.02	0.5	6.8	1.7	0.1

From Table 5.12 it is evident that the annual consumption of only these five goods exceed the carrying capacities of climate change, ecotoxicity (freshwater), particulate matter, eutrophication (freshwater), resource use (fossils), and resource use (minerals and metals)[42]. This is just one example, much more investigation could be done with the LCA impact results of the 625 consumption goods.

[42] Admittedly, I have chosen some of the consumption goods with high impact and used by many people.

5.2.2 Investigating impact per functional unit

The above presentation of the results are the total environmental impacts of Danish annual household consumption. You can split total impacts from a consumption good i into a simple mathematical identity to reveal important drivers of the total impact:

$$Total\ Impact_{Good_i} = Population \cdot \frac{Good_i}{Person} \cdot \frac{Impact}{Good_i}$$

, where Population is number of persons consuming the good, $\frac{Good_i}{Person}$ is how much of the good one person consumes, and $\frac{Impact}{Good_i}$ is the impact per one good i. Not surprisingly, this identity reveals that the total number of people consuming a good (Population) is a key driver for the total impact of a consumption good in Denmark. In that view, the top 10 goods of environmental impact and climate change in Table 5.11 presumably reflect a large environmental contribution from the fact that they are consumed by a very large number of people in Denmark.

The total impacts of all goods are crucial to investigate. However, as the identity above also reveals, the environmental impact per good, $\frac{Impact}{Good_i}$, is a key driver as well. Since my LCA of Danish household consumption reflects the consumption choices made by Danish people, it is also relevant to investigate the environmental impact of choosing to consume different goods per functional unit. For example, "what is the impact of driving a gasoline passenger car for 1 person.km?", or "what is the environmental impact of taking a flight from Copenhagen to Thailand?"[43] Naturally, many physical units are incommensurable per se. For example, you cannot merge 1 person.km and 1 kg into a single unit that makes driving a passenger car 1 person.km and eating 1 kg food directly comparable.

Therefore, to illustrate the point I will analyse "transport in passenger car for 1 km per person", which can then be directly compared in terms of the service that it fulfils. Table 5.12 shows the 25 passenger cars sorted by the highest environmental footprint per km (red colour scaling) and Table 5.13 shows the 25 passenger cars sorted by the smallest environmental impact per km (blue colour scaling)[44].

[43] Importantly, I am only doing accounting-based LCA, not consequential LCA, so the consequence of changing consumption actions cannot be assessed here. Accounting-based LCA is inherently "backward-looking".
[44] An average load factor of 1.43 for passenger cars is used, based on Vejdirektoratet: https://www.vejdirektoratet.dk/side/trafikkens-udvikling-i-tal

Table 5.12: 25 passenger cars in Denmark with <u>highest</u> environmental impact per km

	Single weighted score	Acidification	Climate change	Ecotoxicity, freshwater	Particulate matter	Eutro-phication, marine	Eutro-phication, freshwater	Eutro-phication, terrestrial	Human toxicity, cancer	Human toxicity, non-cancer	Ionising radiation	Land use	Ozone depletion	Photo-chemical ozone formation	Resource use, fossils	Resource use, minerals and metals	Water use
Impact unit	milli Points	mol H+ eq	kg CO2e	CTUe	disease incidence	kg N eq	kg P eq	molc N eq	CTUh	CTUh	kBq U235 eq	kg soil loss	kg CFC-11eq	kg NMVOC	MJ	kg Sb eq	m3 water eq
Rolls-Royce	0.102	0.0033	0.97	6.3	4.1E-08	7.6E-04	1.1E-04	0.0082	7.8E-09	7.6E-09	0.03	3.5E+00	3.0E-08	5.0E-03	2.3E+01	9.1E-06	0.08
Bentley Continental GT	0.099	0.0032	0.96	5.9	4.0E-08	7.4E-04	1.0E-04	0.0080	7.2E-09	7.2E-09	0.03	3.4E+00	3.0E-08	4.9E-03	2.3E+01	8.3E-06	0.08
Mercedes-Benz M-Klasse	0.097	0.0032	0.95	5.7	3.9E-08	7.3E-04	1.2E-04	0.0079	6.9E-09	7.0E-09	0.02	3.2E+00	2.9E-08	4.8E-03	2.2E+01	7.8E-06	0.08
Maserati GranCabrio	0.095	0.0031	0.94	5.4	3.8E-08	7.2E-04	9.5E-05	0.0078	6.4E-09	6.7E-09	0.02	3.2E+00	2.9E-08	4.8E-03	2.2E+01	7.2E-06	0.08
Rolls-Royce Silver Shadow	0.094	0.0031	0.92	5.5	3.8E-08	7.1E-04	9.6E-05	0.0076	6.6E-09	6.8E-09	0.02	3.3E+00	2.9E-08	4.7E-03	2.2E+01	7.5E-06	0.07
Bentley Continental	0.090	0.0029	0.86	5.6	3.7E-08	6.7E-04	1.0E-04	0.0072	6.9E-09	6.8E-09	0.03	3.2E+00	2.7E-08	4.4E-03	2.0E+01	8.1E-06	0.07
Lamborghini Urus	0.090	0.0029	0.86	5.5	3.7E-08	6.7E-04	9.8E-05	0.0072	6.7E-09	6.7E-09	0.02	3.1E+00	2.7E-08	4.4E-03	2.0E+01	7.7E-06	0.08
Ford Mustang	0.083	0.0027	0.82	4.7	3.4E-08	6.3E-04	9.0E-05	0.0068	5.6E-09	5.9E-09	0.02	3.0E+00	2.5E-08	4.2E-03	2.0E+01	6.3E-06	0.07
Maserati Levante	0.082	0.0026	0.77	5.3	3.4E-08	6.0E-04	9.5E-05	0.0065	6.5E-09	6.3E-09	0.02	2.9E+00	2.3E-08	3.9E-03	1.8E+01	7.7E-06	0.08
Mercedes-Benz SLK	0.081	0.0025	0.74	5.5	3.4E-08	5.9E-04	1.2E-04	0.0063	6.9E-09	6.5E-09	0.02	2.9E+00	2.2E-08	3.7E-03	1.7E+01	8.3E-06	0.07
Porsche Cayenne	0.080	0.0025	0.73	5.4	3.4E-08	5.8E-04	1.1E-04	0.0062	6.6E-09	6.3E-09	0.02	2.9E+00	2.2E-08	3.7E-03	1.7E+01	8.0E-06	0.07
Lamborghini Huracan	0.080	0.0027	0.80	4.4	3.3E-08	6.1E-04	7.7E-05	0.0066	5.1E-09	5.6E-09	0.01	2.9E+00	2.5E-08	4.1E-03	1.9E+01	5.7E-06	0.07
Maserati Quattroporte	0.079	0.0025	0.75	4.9	3.3E-08	5.8E-04	8.8E-05	0.0063	6.0E-09	6.0E-09	0.02	2.9E+00	2.3E-08	3.8E-03	1.7E+01	7.1E-06	0.07
Dodge Challenger	0.076	0.0024	0.71	4.8	3.2E-08	5.6E-04	9.4E-05	0.0060	5.9E-09	5.8E-09	0.02	2.8E+00	2.1E-08	3.6E-03	1.6E+01	7.0E-06	0.07
Dodge Charger	0.076	0.0024	0.71	4.8	3.2E-08	5.6E-04	9.4E-05	0.0060	5.9E-09	5.8E-09	0.02	2.8E+00	2.1E-08	3.6E-03	1.6E+01	7.0E-06	0.07
Ford Transit Custom	0.073	0.0021	0.58	6.1	3.2E-08	4.9E-04	1.2E-04	0.0053	7.9E-09	6.7E-09	0.02	2.7E+00	1.6E-08	2.9E-03	1.2E+01	1.0E-05	0.08
Aston Martin Vantage	0.073	0.0024	0.71	4.2	3.1E-08	5.5E-04	7.5E-05	0.0059	5.1E-09	5.3E-09	0.02	2.8E+00	2.2E-08	3.6E-03	1.7E+01	5.8E-06	0.06
Ferrari 488	0.073	0.0024	0.73	3.9	3.0E-08	5.6E-04	6.9E-05	0.0060	4.6E-09	5.1E-09	0.01	2.7E+00	2.3E-08	3.8E-03	1.8E+01	5.0E-06	0.06
Porsche Carrera	0.072	0.0024	0.71	4.2	3.1E-08	5.5E-04	8.8E-05	0.0059	5.1E-09	5.3E-09	0.02	2.7E+00	2.2E-08	3.6E-03	1.7E+01	5.8E-06	0.06
Porsche 911	0.071	0.0023	0.70	4.1	3.0E-08	5.4E-04	8.4E-05	0.0058	4.8E-09	5.2E-09	0.02	2.7E+00	2.2E-08	3.6E-03	1.7E+01	5.5E-06	0.06

Table 5.13: 25 passenger cars in Denmark with <u>lowest</u> environmental impact per km

	Single weighted score	Acidification	Climate change	Ecotoxicity, freshwater	Particulate matter	Eutro-phication, marine	Eutro-phication, freshwater	Eutro-phication, terrestrial	Human toxicity, cancer	Human toxicity, non-cancer	Ionising radiation	Land use	Ozone depletion	Photo-chemical ozone formation	Resource use, fossils	Resource use, minerals and metals	Water use
Impact unit	milli Points	mol H+ eq	kg CO2e	CTUe	disease incidence	kg N eq	kg P eq	molc N eq	CTUh	CTUh	kBq U235 eq	kg soil loss	kg CFC-11eq	kg NMVOC	MJ	kg Sb eq	m3 water eq
Smart Fortwo	0.023171	0.001	0.10140	1.79323	1.13E-08	1.33E-04	5.45E-05	0.0012	2.49E-09	2.96E-09	0.01423	1.06E+00	2.27E-09	9.11E-04	1.50E+00	7.48E-06	2.84E-02
Kia Niro	0.026434	0.001	0.15103	2.98275	1.55E-08	1.68E-04	6.54E-05	0.0018	3.96E-09	3.21E-09	0.01410	1.77E+00	3.37E-09	7.45E-04	2.06E+00	5.55E-06	4.03E-02
BMW I3	0.028436	0.001	0.12783	2.27078	1.27E-08	1.62E-04	7.81E-05	0.0015	3.17E-09	3.68E-09	0.00950	1.17E+00	2.74E-09	1.00E-03	1.68E+00	9.34E-06	3.39E-02
Peugeot 108	0.030734	0.001	0.26803	2.10734	1.63E-08	2.25E-04	3.86E-05	0.0024	2.52E-09	2.66E-09	0.01380	1.85E+00	8.38E-09	1.41E-03	6.14E+00	3.19E-06	2.96E-02
Fiat Panda	0.030844	0.001	0.28387	1.95181	1.62E-08	2.32E-04	3.60E-05	0.0025	2.27E-09	2.55E-09	0.00756	1.86E+00	8.98E-09	1.49E-03	6.52E+00	2.80E-06	3.05E-02
Volkswagen ID.3	0.032687	0.001	0.14540	2.65587	1.40E-08	1.83E-04	9.04E-05	0.0016	3.74E-09	4.26E-09	0.01082	1.25E+00	3.11E-09	1.08E-03	1.88E+00	1.09E-05	3.86E-02
Skoda Citigo	0.033168	0.001	0.29753	2.20103	1.70E-08	2.48E-04	5.22E-05	0.0026	2.60E-09	2.80E-09	0.01135	1.90E+00	9.12E-09	1.54E-03	6.70E+00	3.25E-06	3.16E-02
Tesla Model Y	0.033744	0.001	0.15054	2.74026	1.44E-08	1.88E-04	8.60E-05	0.0017	3.88E-09	4.40E-09	0.01329	1.27E+00	3.12E-09	1.10E-03	1.98E+00	1.13E-05	4.19E-02
Citroen C1	0.034168	0.001	0.31310	2.14917	1.74E-08	2.56E-04	3.90E-05	0.0028	2.52E-09	2.78E-09	0.01379	1.92E+00	9.91E-09	1.65E-03	7.35E+00	3.09E-06	3.04E-02
Suzuki Celerio	0.034407	0.001	0.32038	2.16148	1.74E-08	2.61E-04	4.05E-05	0.0028	2.53E-09	2.81E-09	0.00817	1.95E+00	1.00E-08	1.67E-03	7.32E+00	3.09E-06	3.10E-02
Peugeot 107	0.035041	0.001	0.32361	2.17295	1.77E-08	2.63E-04	3.93E-05	0.0028	2.54E-09	2.82E-09	0.01388	1.94E+00	1.03E-08	1.70E-03	7.63E+00	3.09E-06	3.08E-02
Hyundai I10	0.035076	0.001	0.31322	2.37322	1.78E-08	2.63E-04	4.88E-05	0.0028	2.84E-09	2.98E-09	0.01147	1.95E+00	9.55E-09	1.62E-03	7.02E+00	3.56E-06	3.40E-02
Seat Mii	0.035296	0.001	0.31035	2.44238	1.80E-08	2.59E-04	4.46E-05	0.0028	2.95E-09	3.03E-09	0.01189	1.95E+00	9.57E-09	1.62E-03	6.99E+00	3.72E-06	3.65E-02
Toyota Aygo X	0.035665	0.001	0.32247	2.39108	1.80E-08	2.66E-04	4.50E-05	0.0029	2.86E-09	3.01E-09	0.00867	1.98E+00	9.89E-09	1.67E-03	7.20E+00	3.56E-06	3.37E-02
Kia Picanto	0.035811	0.001	0.32208	2.39328	1.80E-08	2.69E-04	4.91E-05	0.0029	2.86E-09	3.01E-09	0.01155	1.96E+00	9.84E-09	1.67E-03	7.25E+00	3.56E-06	3.43E-02
Suzuki Baleno	0.036122	0.001	0.33015	2.37098	1.81E-08	2.71E-04	4.45E-05	0.0029	2.82E-09	3.01E-09	0.00865	1.98E+00	1.02E-08	1.71E-03	7.43E+00	3.49E-06	3.36E-02
Opel Karl	0.036234	0.001	0.32263	2.47651	1.82E-08	2.67E-04	5.34E-05	0.0029	2.97E-09	3.08E-09	0.00969	1.97E+00	9.88E-09	1.67E-03	7.22E+00	3.72E-06	3.39E-02
BMW iX1	0.036834	0.001	0.16253	3.03158	1.52E-08	2.04E-04	1.02E-04	0.0018	4.29E-09	4.83E-09	0.01211	1.32E+00	3.48E-09	1.15E-03	2.09E+00	1.24E-05	4.32E-02
Citroen C4 Cactus	0.036852	0.001	0.32691	2.48130	1.85E-08	2.70E-04	4.51E-05	0.0029	2.99E-09	3.09E-09	0.01597	1.98E+00	1.02E-08	1.71E-03	7.54E+00	3.73E-06	3.44E-02
Tesla Model 3	0.036856	0.001	0.16349	3.02089	1.53E-08	2.03E-04	9.41E-05	0.0018	4.29E-09	4.82E-09	0.01451	1.33E+00	3.39E-09	1.16E-03	2.14E+00	1.24E-05	4.56E-02

Summing up on Table 5.12 and 5.13, driving a Rolls-Royce 1 pkm is the environmentally most harmful passenger car, whereas a Smart Fortwo is the least environmentally harmful passenger car per pkm. This also proves the point of the previous mathematical identity. The total consumption of driving Rolls-Royce in Denmark would not appear in the top of the most impactful cars if looking at *total* impacts of passenger car transport in Denmark because the 'Population' factor in the previous mathematical identity would be very low. Specifically, there are only 71 Rolls-Royces in the Danish passenger car fleet per 28 April 2024. Therefore, the total impacts of Rolls-Royce transport in Denmark are nothing compared to the total impacts of the 64,297 Volkswagen Golf in the Danish passenger car fleet[45].

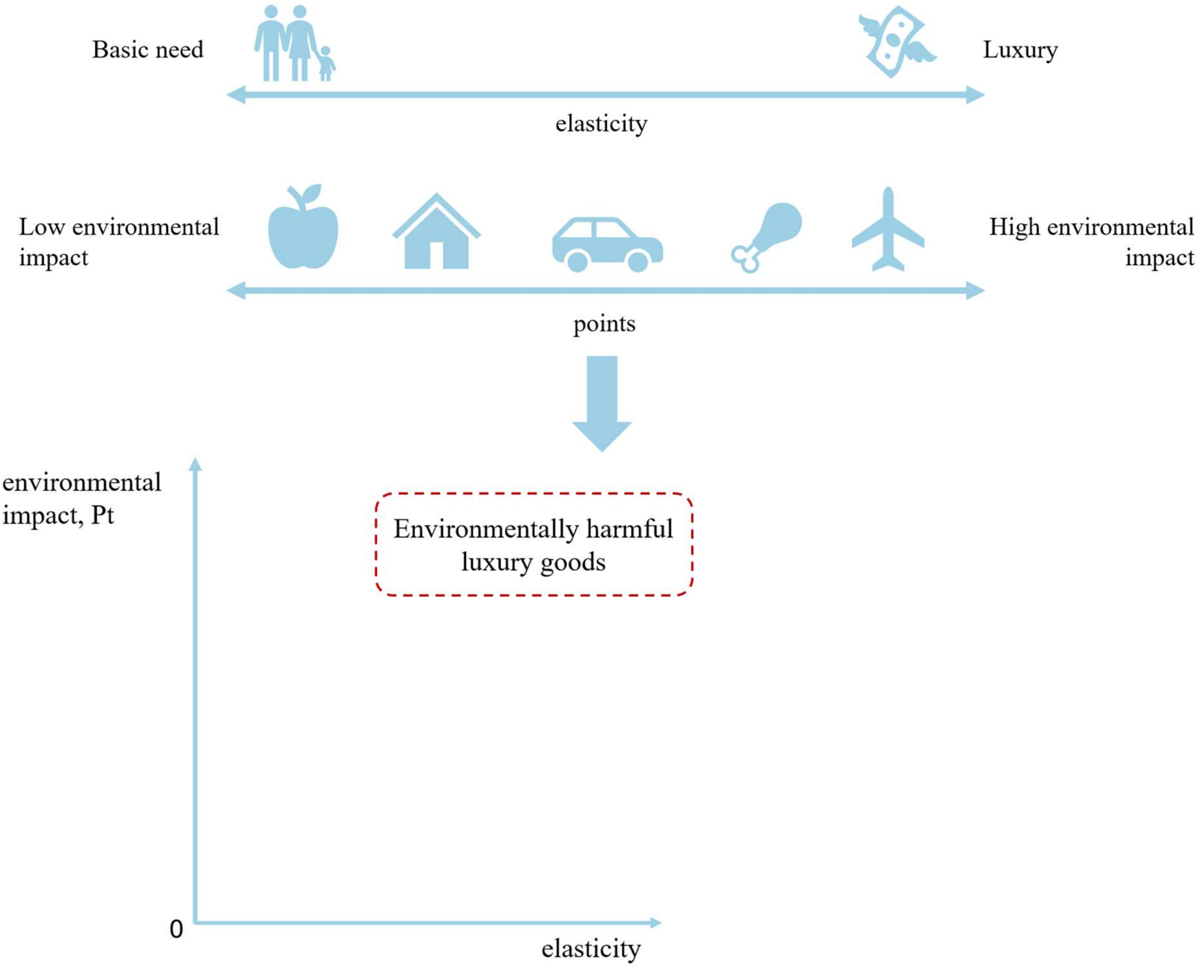
Remember that the sufficiency sharing principle reflects a consumption perspective where a person has a limited remaining Safe Operating Space to use for any consumption purpose. From the individual's perspective of "choosing what to consume", then the action of choosing a Rolls-Royce for transport is naturally much more environmentally harmful than choosing to drive a Smart Fortwo. Moreover, remember the argument of the Sufficiency Consumption Space presented in the theory section: "overconsumption by one person affects the prospects of another, and encroaches into another's (limited) consumption space" (Akenji et al., 2021). The point I am trying to make is that although driving a Rolls-Royce may not appear problematic from a *total impacts* perspective, when applying the perspective of a Sufficiency Consumption Space for Denmark it becomes problematic. Consequently, addressing non-necessary consumption goods with high environmental impact becomes imperative. I will this in the next section.

5.3 Identifying "High Luxury-High Impact" consumption goods

To reiterate, my sub question 6 is "What consumption goods should be focused on when analysing the degree of luxury and environmental impacts of consumption?" In this section I will combine the LCA of annual Danish household consumption from Section 5.2 with an analysis of economic elasticities of all consumption goods to identify the consumption goods that have a high degree of luxury *and* a high environmental impact. This will provide the answer to sub question 6. The intuition is visualized in Figure 5.3 below. Expenditure elasticities allow quantifying the 'degree of luxury' for all goods, and the LCA of consumption goods will quantify their environmental impacts. Since the two spectra are quantitative, I will combine them to identify the goods that both have a high degree of luxury and a high environmental impact, as visualized in the graph in Figure 5.3. I will not illustrate the full graph at the end of the analysis though because it would contain hundreds of data points in one graph, which is not illustrative. But it shows the key intuition.

[45] Data on Danish passenger car fleet per 28 April 2024 provided by: Bilstatistik.dk

Figure 5.3: Combining the analysis of elasticities and LCA to identify environmentally harmful goods with high degree of luxury.



Source: Own illustration, inspired by Oswald et al. (2020).

Importantly, I will only use the combined elasticity- and impact analysis to bring forward the consumption goods with highest degree of luxury and environmental impact. This could be a foundation for policymaking and interventions from a demand-side perspective in Denmark.

5.3.1 Calculating expenditure elasticities of household consumption

I will start out by calculating expenditure elasticities of Danish household consumption at product-level for as many goods as possible. The most detailed nomenclature of Household Budget Survey data is from Statistics Denmark containing 291 consumption categories.[46] This is the most relevant and valid data to access because it is used for calculating the Danish national Consumer Price Indices. I have used real prices to rule out the effect of inflation. I will calculate annual elasticities for 291 consumption categories for the longest period available,

[46] Based on the European Classification Of Individual Consumption by Purpose (ECOICOP) on a 5 digit level, so ECOICOP-5

1994-2022. Next, I will take the median of all the annual elasticities for each good over the 28 years period.[47][48] The full results of the 291 elasticity estimates are provided in Appendix 10. To show a fraction of the results here, I have shown the elasticity estimates for the 12 overall consumption categories in Table 5.15 below. They have been colour scaled with the values and colours in Table 5.14 below, where dark red reflects a high degree of luxury. The immediate impression is that categories like food, housing, household equipment, communication, education, and health are not appearing as having a high degree of luxury. Although I do not focus on needs in the elasticity analysis, it is a strength that it aligns well with the Decent Living Standards framework (Rao et al., 2018) and Theory of Human Need (Doyal et al., 1991). Categories like clothing and footwear, transportation, restaurants and hotels, and recreation and culture are deemed luxurious from the elasticity estimates. Admittedly, basic clothing and footwear and transportation include basic human needs from a theoretical viewpoint, but they might come out as having high degree of luxury in the elasticity estimates due to unsustainable consumption patterns and quantities within the categories. This will be discussed later.

Table 5.14: Colour-scaling of elasticity estimates

Elasticity value, e
$e < 0$
$0 \leq e < 0.5$
$0.5 \leq e < 1$
$1 \leq e < 3$
$e \geq 3$

[47] I will use the median instead of the average, to rule out large outliers. This yielded more valid estimates.
[48] I am obliged to calculate elasticities as aggregate elasticities because I can only access average household consumption data on an aggregated level. This is a delimitation to my analysis, since it would have yielded more valid elasticity estimates by having access to micro data on a household level, from where I could infer elasticity estimates by statistical log-log regression, as done in other studies (Ivanova et al., 2020). However, it was not possible within the timeframe of my thesis to access this data at Statistics Denmark.

Table 5.15: Expenditure elasticity, overall consumption categories, Denmark, 1994-2022 median

Consumption category	Elasticity estimate
Food and non-alcoholic beverages	0,25
Alcoholic beverages, Tobacco and Narcotics	0,30
Housing, Water, Electricity, Gas, and Other fuels	0,49
Furnishing, Household equipment, and -maintenance	0,82
Clothing and Footwear	1,53
Transport	1,49
Communication	0,28
Education	0,93
Restaurants and Hotels	1,57
Miscellaneous goods and services	1,55
Health	0,81
Recreation and Culture	1,46

The full results of elasticities for all 291 consumption goods indicate that Food and Housing appear to be relatively necessary goods – they are mostly blue coloured. Again, while this procedure will not be used for defining the basic needs inventory it strengthens the validity of the analysis that there is alignment between the theoretical Decent Living Standards dimensions and what appears as necessities here.

Next, from the results it is also evident that Clothing, Transport, Recreation and culture, and Restaurants and hotels appear to have a higher degree of luxury, since they are more red. This also aligns well with the theory of human needs and Decent Living Standards (Gough, 2019). Due to the method and data used, there is wide room for discussion about the validity of these results, which I will address later.

To summarize the most luxurious goods from Appendix 10 I have listed the top 20 highest elasticities in Table 5.16 below. I am not fully aware of what "Repair of telephone or telefax equipment" specifically entails. Some of the consumption category labels might appear outdated, since e.g. "telefax" is mentioned. The reason is that the household budget survey data must be comparable over many years, so Statistics Denmark and Eurostat cannot change the category names all the time. Therefore, "repair of telephone or telefax equipment" possibly reflects modern consumption items that are not directly mentioned in the category name.

Apart from that, some of the most luxurious goods are sports equipment, domestic flights, horse riding, accommodation services, storage services, footwear, and motorcycles. One might be surprised that goods like Secondary Education, Passenger transport by train, Passenger transport by bus, and Hospital services are among the top 20 highest elasticity estimates. In the case of secondary education and hospital services it is possibly because only private secondary education and -hospital services are considered, not the Danish public secondary school and -health care system. In terms of Passenger transport by train and bus it is not clear to me why they have so high elasticities. I cannot immediately tell whether it is the case in Denmark or whether it is due to my elasticity calculation method. This would require further investigation.

Due to the possible limitations of my calculation method and type of data, I will seek to strengthen the analysis of identifying goods with high degree of luxury by reviewing literature about what consumption goods are qualitatively deemed highly luxurious. I will do this in the next section.

Table 5.16: Top 20 elasticity estimates, all ECOICOP-5 categories

Consumption item	Elasticity
Repair of telephone or telefax equipment	9.84
Repair of equipment for sport, camping and open-air recreation	8.54
Domestic flights	8.47
Horses, ponies and accessories	6.80
Accommodation services of other establishments	6.35
Removal and storage services	5.71
Repair and hire of footwear	5.11
Secondary education	4.99
Passenger transport by train	4.71
Passenger transport by bus and coach	4.35
Other therapeutic appliances and equipment	3.91
Bundled telecommunication services	3.81
Services of plumbers	3.79
Maintenance and repair of other major durables	3.62
Footwear for men	3.58
Footwear for infants and children	3.57
Motor cycles	3.53
Life insurance	3.53
Services of electricians	3.38
Hospital services	3.37

5.3.1 Identified luxury goods in the literature

In this section I will supplement the above quantitative analysis of luxury goods with a brief qualitative literature review. The reason is twofold. First, there are some goods that did not come out as luxuries in my elasticity analysis but are deemed luxury in the literature. Some examples are Beef ($e = -0.03$), Pork ($e = 0.03$), International flights ($e = 0.93$), Diesel fuel

($e = 0.66$), Purchase of pets ($e = 0.27$), and Boats ($e = 0.45$). Second, there might be consumption goods with a high degree of luxury that are not appearing in the 291 consumption categories. Therefore, I have listed all the luxury goods in identified in relevant literature in Table 9.11 in Appendix 11. Making list of Table 9.11 with the unique names and sorting it by main consumption categories reveals the following 29 luxuries:

Table 5.17: Qualitative identification of luxuries in relevant literature

Food	**Transport**
Meat consumption	Private jet ownership
Eating out weekly	First class air travelling
Animal-based food	Frequent air travel
Palm oil	SUVs, oversized vehicles
Coffee	Vehicle purchase, private road transport
Cocoa	A second (or third) passenger car
Housing	Gasoline and diesel fuel
Overly large homes, mansions	Other vehicle expenses
Secondary vacation homes	Ocean cruises
Household furnishings	Superyachts
Household operations	**Clothing and footwear**
Rubber	Leather
Household electrical appliances	**Recreation and culture**
Health	Entertainment
Private health	Restaurants and hotels
Education	Package holidays
Private education	Expensive hobbies (e.g. horse riding and motorboats)

The way I will incorporate this qualitative classification of luxury goods to my quantitative elasticity analysis, is that I will regard the goods in Table 5.17 luxuries no matter their elasticity estimates. Thus, I will overwrite the existing elasticity values of the consumption items in from

Appendix 10. To assign an elasticity value to them, I will give them the new elasticity value 5.05, which is simply the average elasticity of the top 20 elasticity estimates in my data, from Table 5.16. This exercise is showed in Appendix 12. This operationalization is a subjective decision and can easily be discussed[49].

Summing up, in this section I have calculated elasticities for 291 consumption goods of Denmark and supplemented it with qualitative classifications of luxury goods from relevant literature. These qualitative luxury goods were incorporated into the elasticity analysis by assigning them an average elasticity value of the 20 goods with highest elasticity. In the next section I will merge the elasticity values with the LCA impact values to identify the goods with highest degree of luxury *and* environmental impact.

5.3.2 Merging elasticities and environmental impact into a single value

In this section I will identify the goods with the highest degree of luxury and environmental impact to suggest what type of consumption should be curbed to get back within Planetary Boundaries. The sharing principle is defined in a 'per Danish capita' level, so it could seem intuitive to take the total amounts of consumption of each good and divide by the total population of Denmark to yield a form of "average annual consumption per person". This works fine for the consumption goods that can be assumed to be consumed by the entire population, for example food. However, I also have consumption data where I am certain that not everyone in Denmark takes part in consuming it. For example, the environmental impact of the 71 Rolls-Royces in the Danish passenger car fleet are surely not consumed by everyone. It would be a better assumption to then take the average Danish load factor (1.43[50]) and say that the environmental impacts of the annual consumption of 1 Rolls-Royce should be the total impacts found in the LCA divided by $71 \cdot 1.3 = 92.3$. I find this a more valid way of enabling the comparison of environmental impacts arising from the average annual consumption of each good. I will do this transformation of data into "average consumption per 1 person" in the following.

My LCA data of the 625 consumption goods is activity-based, so they all have a physical unit of consumption[51]. Specifically, the data contains the following consumption units: kg, tons, liter, m^3, pkm, TJ, guestnight, and piece. The unit "guestnight" is used for 1 person staying at a hotel one night and the unit "piece" is used for all the goods that are accounted in

[49] Notably, it was not possible to update the elasticity of all goods from Table 5.6 since some of the consumption good names were not matching well with the elasticity category names.
[50] Vejdirektoratet: https://www.vejdirektoratet.dk/side/trafikkens-udvikling-i-tal
[51] Or at least "non-monetary" unit.

pieces. For example, 1 Iphone is considered "1 (piece of) Iphone". Table 9.13 in Appendix 13 shows how I have converted all the consumption data into "average annual consumption of each good per consumer". Implementing these yields results for all 625 goods. In Table 5.18 I will show the 25 consumption goods with the highest overall impact. Note that you should not dwell too much with a single ranking of a good, but instead focus on the overall tendency in the results. There are many different data sources, assumptions, uncertainties, and limitations behind the results.

Table 5.18: Environmental impact of top 25 consumption goods, (highest), "average annual use of good by one consumer"

Consumption good	Single score, Pt	Acidification	Climate change	Ecotoxicity, freshwater	Particulate matter	Eutrophication, marine	Eutrophication, freshwater	Eutrophication, terrestrial	Human toxicity, cancer	Human toxicity, non-cancer	Ionising radiation	Land use	Ozone depletion	Photochemical ozone formation	Resource use, fossils	Resource use, minerals and metals	Water use
Rolls-Royce	0.817	26.1	7779	50688	3.30E-04	6.055	0.896	65.606	6.23E-05	6.09E-05	224	27698	2.41E-04	39.6	181962	0.072	668
Bentley Continental GT	0.790	25.5	7635	47364	3.19E-04	5.906	0.835	64.002	5.76E-05	5.78E-05	210	27043	2.38E-04	39.0	180185	0.066	629
Mercedes-Benz M-Klasse	0.777	25.2	7596	45631	3.13E-04	5.845	0.948	62.989	5.48E-05	5.62E-05	161	25969	2.34E-04	38.6	179008	0.062	607
Maserati GranCabrio	0.761	25.1	7553	42969	3.07E-04	5.766	0.761	62.459	5.13E-05	5.37E-05	140	25652	2.36E-04	38.6	179766	0.057	641
Rolls-Royce Silver Shadow	0.749	24.4	7323	43659	3.04E-04	5.640	0.768	61.127	5.26E-05	5.40E-05	194	26097	2.29E-04	37.5	173983	0.060	585
Bentley Continental	0.721	23.1	6847	44981	2.97E-04	5.349	0.797	57.959	5.52E-05	5.43E-05	200	25601	2.12E-04	34.9	159922	0.065	595
Lamborghini Urus	0.717	23.2	6891	43869	2.95E-04	5.344	0.785	57.866	5.35E-05	5.33E-05	139	24766	2.12E-04	35.1	160714	0.062	652
Ford Mustang	0.666	21.9	6576	37799	2.74E-04	5.039	0.720	54.458	4.49E-05	4.75E-05	155	23654	2.03E-04	33.6	156309	0.050	529
Maserati Levante	0.654	20.8	6130	42148	2.74E-04	4.816	0.759	52.134	5.20E-05	5.04E-05	132	23453	1.87E-04	31.2	140774	0.062	626
Mercedes-Benz SLK	0.648	20.0	5892	44190	2.72E-04	4.701	0.950	50.533	5.50E-05	5.18E-05	152	23285	1.76E-04	29.7	132644	0.067	576
Porsche Cayenne	0.637	19.8	5833	42849	2.68E-04	4.641	0.918	49.894	5.31E-05	5.06E-05	148	23054	1.75E-04	29.4	131938	0.064	560
Lamborghini Huracan	0.636	21.2	6375	34908	2.63E-04	4.864	0.618	52.683	4.10E-05	4.46E-05	118	23039	2.00E-04	32.8	152685	0.045	525
Maserati Quattroporte	0.629	20.2	5963	39371	2.64E-04	4.662	0.708	50.473	4.81E-05	4.77E-05	126	22906	1.83E-04	30.4	138073	0.057	587
Dodge Challenger	0.604	19.2	5663	38735	2.56E-04	4.452	0.754	48.053	4.75E-05	4.67E-05	157	22401	1.71E-04	28.8	130259	0.056	534
Dodge Charger	0.604	19.2	5663	38735	2.56E-04	4.452	0.754	48.053	4.75E-05	4.67E-05	157	22401	1.71E-04	28.8	130259	0.056	534
Ford Transit Custom	0.581	16.7	4667	48495	2.56E-04	3.949	0.978	42.465	6.32E-05	5.34E-05	191	21975	1.28E-04	23.1	95736	0.081	646
Aston Martin Vantage	0.581	18.9	5654	33884	2.45E-04	4.384	0.599	47.503	4.05E-05	4.25E-05	154	22403	1.78E-04	29.1	134191	0.046	459
Ferrari 488	0.580	19.4	5840	31298	2.43E-04	4.454	0.554	48.249	3.64E-05	4.05E-05	108	21857	1.85E-04	30.1	140339	0.040	473
Porsche Carrera	0.579	18.8	5640	33967	2.44E-04	4.371	0.706	47.107	4.04E-05	4.25E-05	124	21825	1.75E-04	28.8	132862	0.046	458
Porsche 911	0.569	18.6	5581	32625	2.40E-04	4.311	0.675	46.467	3.85E-05	4.12E-05	120	21594	1.74E-04	28.6	132156	0.044	443
Porsche Panamera	0.561	17.6	5208	36609	2.40E-04	4.130	0.780	44.424	4.48E-05	4.40E-05	130	21464	1.58E-04	26.4	118979	0.054	484
Ferrari California	0.558	18.0	5293	34857	2.39E-04	4.150	0.627	44.927	4.24E-05	4.26E-05	114	21428	1.63E-04	27.1	122625	0.050	522
Porsche Macan	0.550	17.4	5149	35268	2.36E-04	4.069	0.749	43.785	4.30E-05	4.27E-05	126	21233	1.57E-04	26.2	118273	0.051	469
Audi Q7	0.547	16.3	4678	41441	2.39E-04	3.858	0.909	41.377	5.26E-05	4.73E-05	141	21188	1.35E-04	23.4	100793	0.066	534
Ferrari Portofino	0.544	17.6	5196	33439	2.34E-04	4.064	0.601	43.995	4.04E-05	4.12E-05	110	21132	1.61E-04	26.6	120924	0.047	502

From this Table 5.18 it is evident that the entire top 25 of most environmentally harmful consumption goods are the passenger cars, when looking at annual use by an average consumer[52].

Summing up, I have hereby merged all the consumption data into a single-dimensioned scale for comparison by transforming all data to a hypothetical "annual use of the good by one average consumer", which should reflect a lifestyle perspective of choosing different consumption patterns. Now, I am ready to merge the elasticity estimates with the LCA impacts. The final step is to match the list of 291 goods from the elasticity analysis with the list of the 625 Danish consumption goods. I will match them manually by assigning the most fitting elasticity category to each of the 625 LCA goods, securing that all goods are included from the LCA perspective.

[52] 7,995 annual pkm on average.

Since both the elasticities and single weighted scores of the LCA are quantitative, I can combine them by addition. The higher the 'degree of luxury' and overall environmental impact, the higher po value they have,. Thus, a higher sum of the two will highlight the goods that are both luxurious and have high impact, as visualized in the conceptual Figure 5.3 earlier. Because the single scores tend to take on a much higher numerical value than the elasticities, I will normalize them to give them equal weight before summing. To do that I will use Min-Max normalization, which rescales values to a fixed range between 0 and 1:

$$Normalized(x) = \frac{x - \min(x)}{\max(x) - \min(x)}$$

Since, in theory, both the elasticities and single scores can take on any positive or negative number, I do not know the true minimum and maximum. However, I will just use the highest and lowest values of my samples as defining the minima and maxima. I find the following in my data:

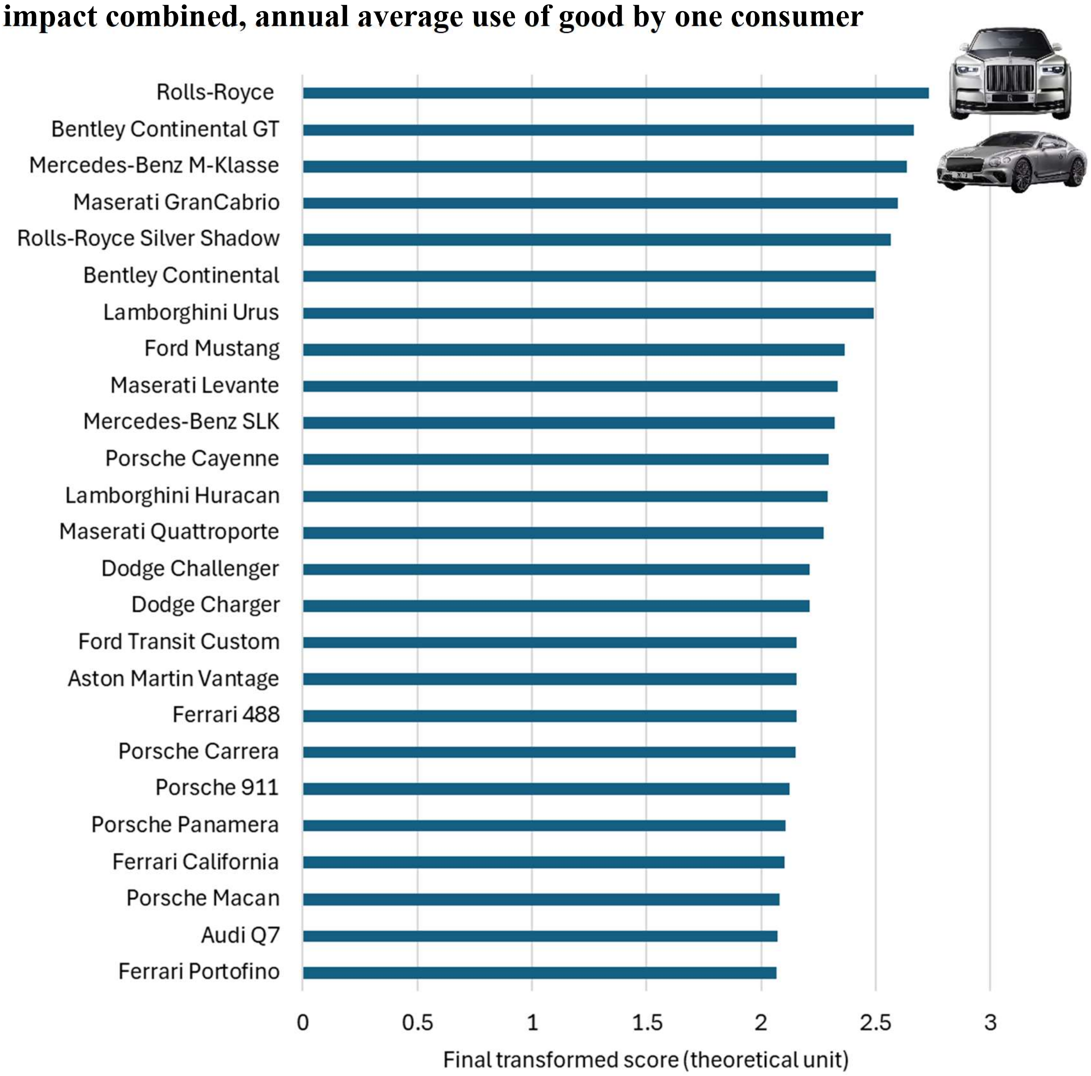
	Sample minimum value	**Sample maximum value**
Elasticity	-21.6	9.84
Impact (single weighted score)	0.000014493	0.8166

Now, I can simply sum them. I do not have any empirical support to define the weighting between them. So, based on a subjective decision I will weigh environmental impact slightly higher than economic elasticity to reflect higher relative importance of impact score than elasticity estimate. I will therefore use the following formula:

$$e_i + 2s_i = v_i$$

, where e_i = elasticity of good i, s_i = single score (in points) of good i, and v_i is the final value of the good from an elasticity- and life cycle point of view. This leads to Table 5.19 on the next page, showing the top 25 consumption goods with highest degree of luxury and overall environmental impact. Again, the top 25 are all luxury passenger cars.

Table 5.19: Top 25 consumption goods with highest degree of luxury and environmental impact combined, annual average use of good by one consumer



Concluding, I have hereby suggested what consumption goods are most relevant to address from an environmental- and luxury perspective. Specifically, curbing the consumption goods in Table 5.19 would have the largest combined effect of environmental mitigation potential and with a minimum probability of causing any significant harm or decrease in wellbeing to anyone. Driving a Rolls-Royce is highly luxurious and cause a large environmental impact. Thus, from a demand-side and "lifestyle" perspective I have hereby suggested what type of excess consumption could be relevant to curb policy-making and interventions. An investigation of the policy- and intervention design is not a part of this thesis, however. But just to mention one possibility in line with my investigation, Oswald et al. (2023) propose a "Luxury focused carbon taxation" that affects high-income households relatively more than lower income households. They find that luxury-focused taxes are marginally better at reducing annual household emissions than a uniform carbon taxation of household consumption. This is also suggested by Gough (2019) who suggests taxing high-carbon luxuries with a "smart Value Added Tax" that differs between goods.

5.4 Sub conclusion of analysis

My analysis has answered sub question 4-6:

SQ 4	How can a new sufficiency-based sharing principle be developed that reflects staying within all Planetary Boundaries and satisfying basic needs?	Analysis Section 6.1
SQ 5	What is the environmental impact of Danish household consumption? And how does it compare to the sufficiency sharing principle?	Analysis Section 6.2
SQ 6	What consumption goods should be focused on when analyzing the degree of luxury and environmental impacts of consumption?	Analysis Section 6.3

I will now conclude on my analysis. First, in section 5.1 I used the concepts of Planetary Boundaries, Decent Living Standards, Consumption Space, and 'sufficiency' to derive a new sufficiency-based sharing principle on a per capita level for Denmark. This sharing principle reflects an equal individual share of the global Safe Operating Space, a part of which must be strictly prioritized for meeting Decent Living Standards, whereafter the remaining part can be used for any other consumption purpose. Effectively, this sufficiency-based sharing principle secures staying beneath the ecological ceiling of Planetary Boundaries and above the floor of satisfying basic human needs.

Second, in section 5.2 I conducted a bottom-up LCA of 625 Danish annual household consumption goods. This served to contrast current household consumption in Denmark to the new sufficiency-based sharing principle, answering sub question 5.

Third, in section 5.3 I analysed the 625 Danish household consumption goods in combination with calculations of expenditure elasticities for each good. To operationalize it, the LCA of Danish consumption was transformed into a theoretical unit to make them comparable on an annual average consumption basis – reflecting a lifestyle perspective. This enabled combining the elasticity estimates with the impact results to identify the consumption goods that are most relevant to curb to get back within the Planetary Boundaries. As stated in the introduction, we need to place limits on 'too much' excess consumption because it theoretically hinders meeting the basic needs of people elsewhere in the world within the ecological limits of the planet (Rammelt et al., 2023). An advantage is that the identified luxurious and environmentally harmful goods can likely be curbed rapidly without objective harm to humans and without causing social disruption (Oswald et al., 2023).

Concluding, I suggest that many other relevant sufficiency-based sharing principles should be developed. In the following, I will discuss the contribution made by this thesis and discuss its strengths and limitations.

6. Discussion

6.1 My research contribution

As stated in the introduction, hundreds of millions of people around the world currently lack access to satisfying basic human needs. This occurs simultaneously with six out of nine Planetary Boundaries being transgressed and moving in the wrong direction towards irreversible Tipping Points. We need to develop scientific and systemic "control instruments" that can grasp the complexity inherent to the environment and human interaction with it. A key challenge is how to understand what the preconditions for everybody are to pursuing a good and decent life – now and in the future. I have addressed this by relying on well-established literature on basic human needs which defines and quantifies the material- and energy requirements for achieving Decent Living Standards universally. Specifically, I applied the concept of a Consumption Space to conceptualize a Sufficiency Consumption Space for Denmark and a sufficiency-based sharing principle for use in PB-LCA.

I am fully aware of the many limitations to my thesis, since it is covering new ground and combine several topics. Nevertheless, I believe I have contributed with the outlines of a new sufficiency-based sharing principle for use in PB-LCA. As part of this endeavour, I have conducted the first literature review of existing sufficiency-based sharing principles. Furthermore, I have investigated Danish household consumption in relation to the new sufficiency-based sharing principle. Finally, I have suggested which consumption goods are relevant to curb from a demand-side perspective, considering their degree of luxury and environmental impacts. In the next section I will discuss strengths and weaknesses of my new sufficiency sharing principle, analysis, methods, data, and theory.

6.2 Discussion of the sufficiency sharing principle

My operationalization of a new sufficiency-based sharing principle has involved many decisions from my side. In addition to the points in Section 5.1 about making it 'sufficiency-based' my intention was that a new sufficiency sharing principle should incorporate the following five aspects:

- ✓ Based on quantitative life cycle assessment in physical non-monetary units
- ✓ Draw upon highest possible data quality and most recent data
- ✓ Apply a consumption-based perspective that reflects people's lifestyles and consumption choices
- ✓ Address multiple anthropogenic environmental impacts in a systemic way
- ✓ Possible to replicate for other countries

It is my choice to incorporate the five elements above, so one could argue that some of them are not relevant to include. However, I have already laid out my argumentation for the incorporating them in my pre-analytic vision, theory- and analysis section and it should become even more clear in the following discussion section. Thus, I will now address some relevant strengths and limitations to the operationalization of the sufficiency sharing principle.

My sufficiency sharing principle has 'equality per global capita' at its core by providing Decent Living Standards for all. Some may find it unrealistic to suggest an equal claim per global capita of the global Safe Operating Space. To address this, you can incorporate inequality to meeting Decent Living Standards as in Millward-Hopkins et al. (2022) who propose a scenario of minimum ideal 'fair inequality' levels that include need-based inequality in animal-based food consumption for the top 1% income earners.[53] This would decrease the size of the remaining Safe Operating Space. In fact, Millward-Hopkins et al. (2022) find that providing Decent Living Standards universally, but not changing current material inequalities within countries, could cause twice the energy consumption relative to a situation where inequalities are only needs-based (Millward-Hopkins, 2022).

From the distributive theory of "Prioritarianism" one could critique the assignment of equal shares of global Safe Operating space per capita to meet Decent Living Standards (Meyer et al., 2006). Prioritarianism holds that the wellbeing of the worst-off should be given strict priority. In the context of developing sharing principles in PB-LCA, this would imply assigning a relatively greater share of global Safe Operating Space to the worst-off. For example, the Global South might need a relatively larger share of global Safe Operating Space per individual than the Global North to adapt to climate change, given the fact that the Global South will be

[53] It was my intention to use the method of Millward-Hopkins et al. (2022) to incorporate a reasonable minimum bound for inequality but I did not have time. This could respond to the arguments that a minimum level of inequality is unavoidable in practice and that higher inequality would create popular resentment and social instability Millward-Hopkins et al. (2022).

more adversely affected by climate change[54]. Overall, there are similarities between Sufficientarianism and Prioritarianism and further research could explore how they can supplement complement each other. In summary, it is a limitation that I have not considered global differences in adverse impacts from climate change.

Schor (2023) includes “necessary” need-based inequality, which reflect that meeting Decent Living Standards in Denmark cause different levels of environmental impact than doing it in another country. For example, Schor (2023) incorporates different needs for heat use due to varying climate and different mobility needs due to regional urbanization levels. Thus, I have included these “necessary” need-based inequality in Denmark. In Millward-Hopkins et al. (2022) they include model different scenarios of inequality, both “unnecessary” need-based inequality in meat consumption, and inequality in non-necessary consumption. An example of the former is differences in meat consumption levels and the latter could be differences in number of annual package holidays. Thus, it is a limitation that I only include “necessary” need-based inequality and not the other two types of inequality from Millward-Hopkins et al. (2022). This can be implemented in future work.

My sufficiency sharing principle showed negative values of some planetary boundaries concerning the remaining Safe Operating Space of Denmark. This is a limitation that I have not addressed, but a simple way to go about it in further work could be to set any negative remaining operating space to 0. Another possibility when encountering a negative budget for a given Planetary Boundary could be to estimate traditional price elasticities to calculate the needed price increase for consumption goods to equate the transgression of the Planetary Boundaries. You could also replicate the method of Gupta et al. (2023) to illustrate how much excess consumption of the top X% richest people in Denmark equates the transgression of the Planetary Boundaries in Denmark.

This raises another question: If there is no remaining Safe Operating Space left after satisfying the Decent Living Standards within the Planetary Boundaries, does this mean there is no room for any other consumption? This is not an easy question. Schlesier et al. (2024) is the only study so far to quantify meeting Decent Living Standards for a global population in different scenarios. They found – strictly speaking – that there is no Safe Operating Space after satisfying Decent Living Standards for a global population in 2050, even when modeling a 100% fossil-free energy system and a global vegan diet. However, this is just one study and

[54] Source: World Resource Institute: https://www.wri.org/insights/ipcc-report-2022-climate-impacts-adaptation-vulnerability

much more research is needed to improve addressing the question comprehensively. For example, one could suggest different DLS subdimensions and amounts of them, and you could improve the complexity in the LCA modelling.

Finally, unlike Schlesier et al. (2024) it is important to understand that there is no technological development included in the LCA modeling of Schor (2023). It reflects meeting the Decent Living Standards in Denmark with existing technologies and provisioning systems. Therefore, incorporating scenarios of future implementation of known technologies and improvements of provisioning systems would be relevant to investigate the environmental impacts of meeting Decent Living Standards in the future.

6.3 Results of the analysis

To discuss the validity of my analysis results, I will briefly compare the elasticity estimates to those found in other studies. All the expenditure elasticity estimates identified in other studies are listed in Appendix 14. Ivanova et al. (2020) find that Food, Housing, Clothing, Manufactured products, and Land Travel have elasticities below 1 and that Services and Air Travel have elasticities above 1 for the EU average, with the latter being the highest. Hertwich et al. (2009) find Services, Mobility, and Manufactured products to be luxuries, whereas Construction, Shelter, Food, and Clothing have elasticities below 1. Narbel et al. (2014) find Food and Energy to be non-luxury and Transport, Clothing and Other to be luxuries. For Denmark specifically, Ivanova et al. (2020) also find Air Travel to have the highest elasticity by far.

In comparison to my results, I also find that Food and Housing are below 1, and Air Travel (domestic) is far above 1, but not Clothing. More work is needed to improve the expenditure elasticity estimates of Danish consumption. I did not have time to interpret the specific data values behind each 291 elasticities estimates, so I cannot immediately explain why some results may appear counterintuitive.

It is also crucial to check the robustness of my LCA impact results of all the 631 goods in the LCA, but I did not have the time to do it in a structured way. Furthermore, there exists no other study conducting a bottom-up LCA for a vast amount of Danish consumption goods, not for any country at all to my knowledge. However, one could take the LCA result of each good and compare it to individual process-based LCAs in the literature. Performing a sensitivity analysis or investigating the robustness of the results by using different LCIA methods would also be beneficial. Additionally, incorporating uncertainty distributions to perform Monte Carlo uncertainty simulations could improve the results. Finally, it would be relevant to have the results and calculations validated by other researchers.

A limitation of my study is that I do not incorporate all different consumption items available on the market in Denmark, which would strengthen the validity of reflecting all Danish consumption as the functional unit. It is not easy to access activity data on actual Danish consumption, since much of the data is privately held by companies and institutions. I was lucky to get activity data on the actual Danish car fleet, international flight trips, and national sales of smartphones. Succeeding with accessing more of this kind of "real consumption data" is a strong recommendation since it would increase the validity and usefulness of investigating Danish consumption from a sufficiency perspective.

Finally, it is a limitation that I do not calculate elasticities and environmental impacts of household consumption from the public sector of Denmark. Public services such as free education, healthcare, state institutions, and self-governing institutions play a large role in Denmark and cause significant environmental impacts. They are not included because it was not possible to gather activity data on these services.[55] Furthermore, I have not addressed environmental impacts from investments carried out by the Danish people, although they are officially regarded as being a part of Danish consumption according to the Danish Energy Agency (2024).[56] Having discussed the results, I will discuss the methods in the next section.

6.4 The methods applied

6.4.1 Using Decent Living Standards

One could object to the Decent Living Standards framework arguing that factors such as upbringing, healthy relationships, and security are also human needs and should be modelled accordingly. While the discussion of the minimum basic needs is indeed relevant, it is important to emphasize that the Decent Living Standards proposed by Rao et al. (2018), Millward-Hopkins et al. (2020; 2022), and Schor (2023) focus exclusively on the minimum material- and energy requirements that are *preconditions* for satisfying the three basic human needs: Health, autonomy, and minimally impaired social participation.

Also, one could suggest variations in the specific material- and energy requirements for meeting Decent Living Standards. For example, Schor (2023) includes a small amount of air

[55] They are easier to include from a top-down perspective that uses monetary values of the public services to estimate environmental impacts, see for example the Denmark's Climate Status and Outlook 2024 report by The Danish Energy Agency (2024)[55].
[56] The only part of investments that I have included is housing because the purchase of housing is considered investments in The Danish Energy Agency (2024).

transport, which Schlesier et al. (2024) do not. Similarly, there is no objective standards for whether each person or only each household should be modeled to have 1 smartphone, TV, or laptop. Furthermore, Schor (2023) notes that his Decent Living Standards LCA model includes generic and high-level inventory data, which introduces uncertainty to the results. This is a significant limitation to my thesis, underscoring the need for more studies to investigate other DLS inventories.

6.4.1 LCA of total annual Danish consumption

In calculating the LCA of Danish annual household consumption, other studies apply a top-down approach instead of the bottom-up approach. Each method has its advantages and limitations, and they can complement each other. While I do not have space for an extensive discussion on the two methods here, I can refer to a thorough discussion in Sala et al. (2019) and Millward-Hopkins (2022).

Climate change is arguably the most discussed environmental issue, so one might question its valuation and weighting in my LCA of Danish household consumption. During the development of the life cycle impact assessment method Environmental Footprint 3.1, which I applied, surveys of the EU population and LCA experts revealed that climate change ranked highest in all three LCA main Areas of Protection: Human health, ecosystem quality, and natural resources (Jungbluth, 2024). Consequently, climate change is considered highly important in the development of the Environmental Footprint 3.1 method. For example, the weighing factor of Climate Change is 21.1% compared to Land use at 7.9%.[57][58]

There is a crucial point from traditional LCA literature that must be transparently addressed: LCAs do not show real impacts but rather impact *potentials,* due to the inherent simplicity in modeling real-world complex phenomena. Therefore, my analysis reflects the impact potential of Danish household annual consumption[59].

As mentioned in the pre-analytic vision and theory section, the Decent Living Standards framework by Rao et al. (2018) and Millward-Hopkins et al. (2018) is similar to the Doughnut framework by Raworth (2017). It is possible to replicate my investigation using the Doughnut as the social foundation. However, I chose to follow the Decent Living Standards in Millward-

[57] See Appendix 8 for all weighting factors.
[58] All the weighting factors of the Environmental Footprint 3.1 method are in Appendix 8.
[59] There are several reasons for this, some of them being that it is extremely complex to account for all real interactions in the environment – including non-linear interactions. Also, my data is mixed from different years and covers activities occurring at different places, so the results are temporally and spatially simplistic. Moreover, my consumption activity data is naturally incomplete, and I rely on many simplifying assumptions and default LCAs from the EU Consumption Footprint and Ecoinvent 3.10.

Hopkins et al. (2020) because Schor (2023) has conducted an LCA for meeting Decent Living Standards in Denmark based on this. I did not have any similar human needs LCA model that could align with the Planetary Boundaries to create a Sufficiency Space for Denmark. This is not to say that it cannot be done. Also, the social floor of the Doughnut includes social categories, and it was not my interest to include these more social areas in the modeling, as outlined in the theory section. Nonetheless, exploring synergies and differences between the Doughnut and Decent Living Standards would be relevant for future work. Recently, Schlesier et al. (2024) use the Doughnut frameworks, but they end up boiling it down to the Decent Living Standards by excluding some social categories from the Doughnut, so perhaps the two frameworks will be completely merged in the future.[60]

6.4.2 Expenditure elasticities

It can be argued to leave out the elasticities from the investigation of what consumption goods should be curbed in addressing overconsumption. However, I included it to identify the "degree of luxury" of various consumption goods. This method is supported by numerous studies in the research area (Oswald et al., 2023; Starr et al., 2023; Ivanova et al., 2020; Vita et al., 2019; Steen-Olsen et al., 2016; Ivanova, 2015; Hertwich et al., 2009). According to these studies, addressing excess consumption is necessary given the limited global consumption space, where excess consumption by one person may hinder the satisfaction of basic needs for people elsewhere. It is, however, a limitation that I have not calculated elasticities across income- or expenditure quintiles for Denmark, since elasticity estimates differ across income groups. Thus, it would make the analysis more granular to consider income levels as in Ivanova et al., (2020), but it was not possible to get data for Denmark on this.[61]

On a more general level, one should be careful when calculating elasticities at an aggregate level (Ivanova, 2015). Expenditure elasticity estimates vary with different socioeconomic groups and contexts such as culture and geography. Consequently, it is a main limitation to use aggregate data compared to micro data on household consumption (Ivanova, 2015). In more general terms, elasticity analysis based on aggregated data may suffer from aggregation bias arising from complex interactions between individual characteristics and

[60] A strength to the Doughnut framework compared to the DLS is that it is widely known internationally and already implemented in some cases, like the Danish building sector in Birgisdottir et al. (2023).
[61] I consulted Statistics Denmark to ask to data to calculate this, but it was not available. It would have increased the validity of my analysis to include how the same goods can be considered a luxury for one income group but not for another and put more focus on the consumption patterns of the most wealthy people.

income changes (Dybczak et al., 2014). I have done six things to meet the limitations of using expenditure elasticities and improve its validity.

1. **Exclusion from Human Needs floor:** I have not used the elasticities to define the human needs floor. For this I have used Millward-Hopkins et al. (2020) and Schor (2023).
2. **Use of Danish household data:** I have used Danish household expenditure data for the analysis of Denmark. This is a strength compared to using for example an EU average.
3. **Continuous spectrum:** I have avoided using the elasticity value of 1 as a threshold to binarily classify goods as luxuries or not. Instead, I have used the elasticity value on a continuous spectrum. This is inspired by Oswald et al. (2023) who propose a luxury tax on carbon that incorporates the elasticity values. In this way, I avoid the issue of many consumption goods being close to an elasticity of 1.
4. **Long-term median values:** I have used data on the longest period possible and found the median value to try ruling out annual-specific variation. However, this must be a balance because elasticity trends may change over time.
5. **Weighted results:** I have put less importance of the elasticity estimate into the final sufficiency sharing principle by giving double the weight to the normalized impact results.
6. **Qualitative supplementation:** Finally, I have supplemented the quantitative elasticity estimates with qualitative luxury consumption categories from relevant literature. This should strengthen my analysis in securing the inclusion of most relevant luxuries no matter the elasticity estimates of my calculations. I am aware that this is a subjective decision to do, and one could view it as a limitation as well.

Despite these six measures, much more work can be done to improve the calculation and use of expenditure elasticities. For example, accessing micro data on Danish household consumption and calculate elasticities by conducting statistical log-log regressions on micro data to infer the estimates of expenditure elasticity would enhance the accuracy and validity (Gough, 2017; Oswald et al., 2020). However, I did not have access to such data, which I consider a main limitation to my investigation.

Another potential issue with using expenditure elasticities is that the data on a given consumption category often contain several goods. I addressed this by using the most granular expenditure data available, although this amounted to no more than 291 consumption categories.

6.1 The data used in the analysis

In terms of the data on Danish private consumption for the LCA, it is a strength that I have managed to incorporate 625 consumption goods. It is also a strength that my data on the Danish passenger car fleet, international flights, domestic flights, and smartphone sales are reflecting the actual activities of 2023.[62]

A limitation is that food could not be modeled more granularly, since it is one of the consumption categories with the highest overall environmental footprint (Schlesier et al., 2024). It was my intention to align with the Climate Food Database developed by CONCITO and 2.0 LCA Consultants[63]. I received their data and conducted a LCA on all 500 food items, but due to technical challenges in getting valid results there was not enough time to receive support from 2.0 LCA Consultants to solve it. Thus, it would be highly relevant to include moving forward.

Heating and electricity use make up a large part of current environmental impacts in Denmark (The Danish Energy Agency, 2024). Therefore, I manually modeled their respective LCAs with detailed data from the Danish Energy Agency's most recent data, instead of just using the existing heating and electricity LCAs in the Ecoinvent 3.10 database. I see this as a strength to my analysis because it yields more valid results.

As for conducting a LCA on the entire fleet of Danish passenger cars I received the actual Danish fleet data per 28 April 2024 from Bilstatistik.dk with permission to use for my thesis. Naturally, it is not simple to conduct LCAs for all passenger cars currently on the road in Denmark, so I chose to manually gather data for the most relevant parameters and implement those with the existing LCAs in Ecoinvent 3.10 for passenger cars. Therefore, I looked up fuel intensity, weight, propulsion type, and main country of production for the 239 different car models that make up the first 90% of the car fleet.[64] It is an advantage of my analysis that I have managed to get data on the actual car fleet and include key parameters in the model, however, I am fully aware that much more work could be done to improve these LCAs. For

[62] Specifically, the passenger car data, international flight data, and national smartphones sales data are not publicly available, I have contacted the relevant actors to access it for my thesis.
[63] Access here: https://denstoreklimadatabase.dk/en. It only accounts for CO2e so I had to do the LCA.
[64] The reason for not looking up the last 10% is that this includes the remaining 3,243 car models, which would be very time consuming.

example, I did not have specific data on the materials included in each car, so I had to rely on the default values from the Ecoinvent 3.10 database.

As mentioned earlier, the data behind the elasticity estimation is reliable Household Budget Survey data from Statistics Denmark, which is a strength to the analysis. It is consistent over time and since Denmark follows the ECOICOP nomenclature[65], my method can easily be applied to other EU countries. However, even for such highly validated data that is normally used for estimating national inflation levels, issues can be found. Oswald et al. (2020) mention that "consumption expenditure surveys come with several caveats including survey design, non-response bias, sampling bias and so forth". Another well-known issue with Household Budget Survey data is the underestimation of the consumption of super-rich households due to non-responses (Ivanova et al., 2020). In Blanchet et al. (2022) they have tried to account for this bias of the rich. Taking these issues into consideration, I still believe it is high quality data and useful for my research purpose.

6.1 The theory applied

6.1.1 Decent Living Standards and basic human needs

It is a strength that Schor (2023) has modelled the environmental impacts of meeting the Decent Living Standards specifically for Denmark, an aspect not addressed by Schlesier et al. (2024). Another reason for using Schor (2023) for the human needs floor of the Sufficiency Consumption Space is that the impact categories align with the PB-translated LCIA categories of the ecological ceiling in my Sufficiency Space.

However, a limitation of Schor (2023) is that it did not consider future improvements and implementation of known technologies such as providing renewable energy. It reflects only the current infrastructure, which will undoubtedly improve over time, both the technologies and provisioning systems. Schlesier et al. (2024) operationalize this with a scenario of 100% renewable global energy system and a global pescetarian diet. Incorporating such scenarios to my sharing principle would have been a strength. It can be addressed in further work by enhancing the LCA model of Schor (2023).

Much can be discussed about what constitutes basic human needs, how they are quantified, and the measures used. Other well-known theories are Martha Nussbaum's Capabilities Approach (2000), and Deci and Ryan's (1985) Self Determination Theory. However, the Theory of Human Need by Doyal et al. (1991) is to my knowledge the only theory

[65] ECOICOP: European Classification of Individual Consumption according to Purpose

quantified in terms of specific material- and energy requirements for meeting the preconditions of satisfying basic needs. Therefore, I believe it is the only theory of basic needs that can be investigated with LCA against Planetary Boundaries.

6.1.2 The Planetary Boundaries framework

The framework of the Planetary Boundaries serves as a key theoretical foundation for my thesis. It is internationally recognized as the foremost global framework to quantify the limits to human perturbations of the Earth system domains, but it is also worth noting that it is constantly being improved. A significant strength of using the Planetary Boundaries framework is that it allows for a systemic investigation of all critical Earth systems[66], rather than focusing solely on climate change. This systemic approach is highlighted in the most recent update of the Planetary Boundaries, and the systemic scope is the main reason applying it in my thesis:

> *"Currently, anthropogenic perturbations of the global environment are primarily addressed as if they were separate issues, e.g., climate change, biodiversity loss, or pollution. This approach, however, ignores these perturbations' nonlinear interactions and resulting aggregate effects on the overall state of Earth system. Planetary boundaries bring a scientific understanding of anthropogenic global environmental impacts into a framework that calls for considering the state of Earth system as a whole."* (Richardson et al., 2023)

A discussion related to the Planetary Boundaries is what threshold value should be used to define carrying capacities. I have used Planetary Boundary values from Sala et al. (2020)[67]. They use the upper limit of the global Safe Operating Space as the LCIA-based Planetary Boundary limits. However, as discussed in Schlesier et al. (2024) you could argue that the boundary used should be different, for example at the upper end of Zone of increasing risk (Richardson et al., 2023). Essentially this boils down to the question of the politically acceptable risk of exceeding Planetary Boundaries.

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[66] Also, if you want to make an LCA with more weight on climate change, you can edit the weighting factors that are used to yield the single weighted score.

[67] They have not yet been updated to the most recent update on the Planetary Boundaries (Richardson et al., 2023). This would have further strengthened my analysis. Some of the most recent development is that control variables are suggested for all Planetary Boundaries with new metrics for Novel Entities and Land System Change, and that local and regional boundaries are defined for some Earth systems, for example freshwater change, biogeochemical flows of phosphate, and land system change (Rockström et al., 2023; Richardson et al., 2023).

Two additional topics not directly assessed in my thesis are Circular Economy and technological development. As highlighted in my pre-analytic vision, they can contribute to sustainable development, but more actions are needed as suggested in this thesis. Circular Economy and technological efficiency improvements do not resolve the crucial challenge of the scale of the economy. This is where the Planetary Boundaries play a key role.

There is also scientific debate whether technological efficiency improvements in the long-term *increase* the total use of resources or decrease.[68] While Circular Economy may provide benefits for sustainable development, the IPCC (Creutzig et al., 2022) comments that many proposals on Circular Economy do not incorporate thermodynamic constraints that limit the potential of recycling or ignore the considerable amount of energy needed to reuse materials. Secondly, Creutzig et al. (2022) add that demand for materials and resources will likely outpace efficiency gains. Therefore, technological improvements and the Circular Economy are indeed beneficial tools needed for sustainable development, but they are insufficient on their own.

6.2 Consumption status of Denmark

Although it is not part of my research question, I will conclude by showing the direction Denmark is heading regarding key consumption areas and inequality in relation to the Sufficiency Consumption Space. Based on a brief assessment. I find that Denmark is not heading it the right direction for Food, Housing, and Mobility, and there is inequality in who are responsible for this consumption and its impacts[69][70].

Food
The supply of animal-based protein available for consumption (g/cap/day) in Denmark as share of total protein supply has increased from 64% in 2002 to 67.3% in 2020.[71]

[68] This is stressed in the most recent IPCC report (Creutzig et al., 2022): "The emissions reducing effects of energy efficiency improvements are diminished by the energy rebound effect, which has been found in several studies to largely offset any energy savings (Font Vivanco et al., 2022; Rausch et al. 2018; Colmenares et al., 2020; Stern, 2020; Brockway et al., 2021; Bruns et al., 2021)."
[69] Denmarks' Climate Status and Outlook 2024: https://ens.dk/en/our-services/projections-analyses-and-models/denmarks-energy-and-climate-outlook
[70] Documentation is provided in Appendix 15. Data is primarily from Statistics Denmark.
[71] This is not the direct consumption per capita but the food available for consumption.

Housing
Average dwelling area per capita (m^2) has been increasing steadily from 2010-2024.
The dwelling size category that is currently increasing the most in % is the dwellings of "175 m^2 and above"

Mobility
Passenger car transport makes up 70% of total annual passenger-km travelled in Denmark of all means of transportation.
Sales of electric vehicles is increasing exponentially, but the number of total petrol cars in Denmark has been nearly constant at around 1.8 million from 2000-2024.
18% of all Danish households have two passenger cars or more.
We are driving fewer people together in a passenger car per trip.
There are more passenger cars per capita. In 1990 there were 0.31 passenger cars per capita and in 2022 there are 0.47 passenger cars per capita.
In 2000, the share of SUVs of total new car purchases was 0.6%. It is 55% in 2023.

Inequality
The higher the income level, the higher the total consumption expenditure level for all consumption categories.[72]
Some of the largest relative differences between the highest consumption expenditure interval and the lowest are in the categories "Other major durables for recreation and culture", "Purchase of vehicles", "Package holidays", "Household textiles", and "Maintenance and repair of dwellings".
It is consistent that the higher the income, the larger the average dwelling size in m^2.
There is a high degree of inequality in personal carbon footprint when comparing the top 1% carbon footprints to the remaining 99%.
There is a significant inequality in energy use across income quintiles.

[72] only with very few exceptions

6.3 Sub conclusion of discussion

I have now concluded my discussion section. First, I addressed my research contribution in conceptualizing a new sufficiency-based sharing principle for PB-LCA. Next, I discussed strengths and limitations to my results, methods, data, and theory. I see clear strengths to my thesis, but since I am covering new ground, there are just as many limitations that should be improved in future work. Finally, I highlighted the status of key sufficiency areas of Danish, noting that are all heading in the wrong direction. With this, I have answered my main research question and all sub questions, which leads me to the conclusion of the thesis.

7. Conclusion

In this thesis, I developed a new sufficiency-based sharing principle that ensures the satisfaction of basic human needs for everyone while respecting all the Planetary Boundaries, with Denmark as the case study. Drawing upon the Decent Living Standards framework, life cyclase assessment and the Planetary Boundaries I conceptualized a Sufficiency Consumption Space for Denmark at an individual level. From this I could derive the new sufficiency-based sharing principle. Furthermore, I conducted a bottom-up LCA of 625 Danish household consumption goods to relate current household consumption patterns of Denmark to the new sufficiency sharing principle. Additionally, I combined the LCA of Danish household consumption with an analysis of expenditure elasticities to suggest which environmentally harmful luxury goods should be curbed to get back within the Planetary Boundaries in Denmark. Given the conceptual and explorative nature of this novel sharing principle, much more development is needed. Finally, I showed that Denmark is heading in the wrong direction for entering a Sustainable Sufficiency Space.

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9. Appendices

Appendix 1: String search

First, I made a brainstorm of relevant search words that lead to the following string search in Scopus, Web of Science, and Google Scholar:

Table 9.1: String search used

Subtopic 1		**Subtopic 2**		**Subtopic 3**		**Subtopic 4**		**Subtopic 5**
Sufficiency		"Sharing principle(s)"		Absolute environmental sustainability		"Life cycle assessment"		Planetary boundaries
Wellbeing		"Allocation principle"		Absolute environmental sustainability assessment		LCA		Ecological limits
Well-being	AND		AND	Absolute sustainability	AND	"Life cycle analysis"	AND	Earth system boundaries
"Human needs"				AESA		"Life-cycle assessment"		
Enough						Lifecycle assessment		
Sufficiency-based						Absolute environmental sustainability-based life cycle assessment		

Appendix 2: Six characteristics of basic human needs

First, human needs are *objective*. The truth of the claim that "a person needs clean drinking water" depends on objective physiological requirements of human beings, not the subjective perception of it. In contrast, "a person want to have a glass of wine" or "prefers beer to wine" depends on the person's subjective wants, beliefs and attitudes toward the objects.

Second, human needs are *plural*. This means they cannot be added up and summarized in a single number (O'Neill et al., 2018). Third, needs are *non-substitutable*, meaning deprivation in one domain of need-satisfaction cannot be traded off against increase in another. For example, "more education is of no help to someone who is starving". However, the opposite can happen; A gain in one need can hinder the satisfaction of another need, such as more mobility-related polluting activities resulting in increased harmful consequences for human health.

Fourth, needs are *satiable*. The amount required to achieve a sufficient level of health and autonomy diminishes as their quantity increases, eventually plateauing (Gough, 2017).

Thus, for the needs of health and autonomy, thresholds can be conceived where serious harm is sufficiently avoided such that acceptable levels of social participation can take place (Doyal et al., 1991). Research supports this point. For example, after achieving adequate nutrition and housing no further significant gains in those wellbeing-dimensions are possible (Steinberger et al., 2010; Lamb & Steinberger, 2017;Millward-Hopkins et al., 2020; Fanning et al., 2019).

Fifth, human needs are *cross-generational*. This follows from asserting that the basic needs of future generations of humans will be the same as those of present humans, at least until the genetic makeup of humans changes significantly. Therefore, human needs theory brings along a high degree of knowledge about the constituents of future peoples' wellbeing. This is very fortunate when aiming for sustainable development that imposes intergenerational equity dilemmas.

Finally, human needs have a solid ethical grounding that preferences and wants do not: They come along with claims of justice and equity (Gough, 2017). Specifically, universal needs place ethical obligations on people and justice claims on societal institutions. An important corollary is that meeting human needs should be given strict priority over meeting individual wants and desires, whenever the two conflicts or when resources are scarce. In other words, "present human needs trump present and future consumer wants" (Gough, 2017).

If a plethora of need satisfiers exists across time, space, and cultures, how can they be quantified to enable life cycle assessments of them? To answer this, the Theory of Human Need (Doyal et al., 1991) goes a step further to elaborate on a set of 'universal need satisfier *characteristics*'. These are not to be confused with the need satisfiers. That is, to bridge the universal needs and the contextual need satisfiers, Doyal et al. (1991) identify the universal characteristics that all need satisfiers have in common across time and space. For example, 'calories per day' is a universal characteristic of nutrition, which exist as many different need satisfiers. Similarly, 'shelter from the elements' and 'protection from disease-carrying vectors' are two universal characteristics of dwellings, which is a need satisfier.

Appendix 3: Decent Living Standards inventories

Table 9.3.1: 11 Decent Living Standards dimensions, Rao et al. (2018)

Dimension	Subdimension
1. Nutrition	Food
	Cold storage

2. Shelter	Durable, resilient homes
3. Living conditions	Sufficient and safe space Lighting Sanitation Water Waste
4. Clothing	Clothing and footwear
5. Health care	Sufficient and accessible and adequate health care facilities
6. Air quality	Maximum ambient particulate matter concentration (PM2.5)
7. Education	Schooling with adequate facilities and staff
8. Communication	Household access to communication
9. Information	Household access to information
10. Mobility	Access to motorized mobility options
11. Freedom to gather/dissent	Adequate and safely accessible public spaces

Table 9.3.2: Decent Living Energy, Millward-Hopkins et al. (2020)

Basic need category	GJ/capita	% of total energy use	Sub category	GJ/capita	% of total energy use
Total	15.6	100			
Nutrition	3.2	20.5	Food	2.7	17.3
			Cooking appliances	0.3	1.9
			Cold storage	0.2	1.3
Shelter and living conditions	1.5	9.6	House construction	0.8	5.1
			Thermal comfort	0.7	4.5
			Illumination	0.0	0
Hygiene	1.6	10.3	Water supply	0.1	0.6
			Water heating	1.4	9
			Waste management	0.1	0.6
Clothing	0.6	3.8	Clothes	0.3	1.9
			Clothes washing	0.3	1.9
Healthcare	1.4	9		1.4	9
Education	0.4	2.6		0.4	2.6
Communication and information	0.5	3.2	Phones	0.0	0.6
			Computers	0.1	0
			ICT networks and data	0.4	2.6
Mobility	3.1	19.9	Vehicles	2.3	14.7
			Transport infrastructure	0.8	5.1
Other	3.3	21.2		3.3	21.2

Table 9.3.3: DLS inventory of Millward-Hopkins et al. (2022)

DLS dimension	Subdimension	Amount	Unit	Comment
Nutrition	Food	2000	kcal/pers/day	Age dependent (up to 2150kcal). 93% plant-based, 3% meat based, 4% other animal.
	Cold storage, fridge-freezer	0,25	per pers/yr	
	Cooking, stove	0,25	per pers/yr	For top 1% population: 80% plant-based, 20 % meat-based
Shelter	Living space	20 m2 communal floor space per household + 15 m2 floor space per pers		
	Thermal comfort	20 m2 communal floor space heating + 15 m2 floor space heating per pers		climate dependent
	Illumination	2500	lm/house, 6 h/day	
	Water supply	50	L/pers/day	
	Water heating	20	L/pers/day	
	Waste management infrastructure			Provided to all hh
Clothing	Clothes	4	kg new clothing/pers/yr	
	Washing facility	100	kg clothes washing/pers/yr	
Health	Healthcare	200	m2 floor-space/hospital bed	Hospitals
Education	Education	10	m2 floor-space/pers	Schools
Communication & Information	Phones	0,25	per pers/yr	>10 yrs old person
	Computer	0,25	per pers/yr	
	Networks and data			Provided to all hh
Mobility	Vehicle	4,900-15,000	pkm/pers/yr	population density dependent Vehicle production consistent with providing this
	Infrastructure			1000 pkm air travel, 1000 pkm walking and bicycle, and then 40% rail, 40% bus, 20% car for remaining pkm

Table 9.3.4: Schor (2023) additions/changes to DLS of Millward-Hopkins et al. (2020)

DLS Dimension	DLS subdimension	Added/changed items
Food	Food	20% added food waste at consumer
Shelter	Cold storage	120 kWh/yr
	Food preparation	6 MJ/kg (50% of food is heated)
	Living space	69 m2/hh 14.08 m2/pers
	Lifetime of house	50 years
	Thermal comfort	61.2-18.7 MJ/pers/yr No heating for 15.6-21.1 deg. C Lifetime of equipment: 15 years
	Illumination	0.0118 GJ/m2/yr 30 LED/hh Lifetime of LED: 20yrs
	Furniture	1000 kg/household Lifetime: 25 years
Hygiene	Water heating	50% electricity, 25% district natural gas, 25% district other
Clothing	Clothes	3.03 kg/pers/yr

	Washing machine	1 washing machine/hh Lifetime: 20 yrs
Health	Healthcare operations	65.7-89.4 MJ/pers/yr
Education	School	Lifetime of school: 50 yrs Energy required: 0-32 MJ/cap/yr
Communication	Phone	356.5 g/phone Phone energy use: 27 MJ/cap/day Lifetime of phone: 5 yrs
	Computer	1 computer/hh Use: 2 hrs/day
Mobility	Airplanes	1067 pkm/pers/yr
	Bicycles	1251 pkm/pers/yr
	Car	516-2383 pkm/yr
	Bus + Train	1033-4766 pkm/yr

Note: Assumed household size: 4.9 people

Table 9.3.5: Parameters in model of Winter-Schor (2023)

Additional parameters	**Amount**	**Unit**
People per household	4,9	persons
m2 in dwelling	20 + n*10	m2, n=persons
Lifetime of dwelling	50	years
Heating not required for	15,6-21,1	degree C
Lifetime of heating equipment	15	years
LED energy intensity	0,0118	GJ/m2/year
Lifetime of LEDs	20	years
Lifetime of furniture	25	years
Water heating input	50% electricity, 25% district heat (natural gas), 25% district	
Energy intensity of water heating	70,1-161,2	MJ/pers/year
Lifetime of washing machine	20	years
Energy intensity of healthcare operations	65,7-89,4	MJ/pers/year
Lifetime of schools	50	years
Pupil age	5-13	years
Energy intensity of school activities	0-32,9	MJ/pupil/year
Use of computer	2	hours/pers/day
Weight of phone	356,5	g
Energy intensity of phone use	27	MJ/pers/day
Lifetime of phones	5	years
Age for phone use	10	years and above
Flights	1	per 3 years
Bicycle use, around	4	km/pers/day
Ferry passenger transport	not included	
National electricity grid	included	
Number of households per country	included	
Lifetime of fridge	included	
Cooking energy intensity	included	
Lifetime of stove	included	
Dwelling type (SFH/MFH)	included	
Urbanization rate	included	
Persons per household	included	
National water grid	included	
National age distribution	included	
Share of electric vehicles	included	

Figure 9.3.6: DLS inventory of Schlesier et al. (2024)

DLS dimension	Subdimension	Need satisfier	Amount	Unit
Nutrition	Food	Calories, proteins, micro-nutrients	2000	kcal/pers/day
	Cold storage	Refridgerator (100L)	0,2	per pers/yr
	Cooking	Clean stove	0,2	per pers/yr
Shelter	Building	Solid wall, roof, minimal floor space	10	m2/pers/yr
	Final energy use	Electricity use	954	MJ/pers/yr
		Heating	1455	MJ/pers/yr
		Energy,water, sanitary infrastructure		Provided to all hh
	Hygiene and sanitary	Toilet	0,2	per pers
		Water supply	18,25	m3/pers/yr
	Light	Illumination	73	klmh/pers/yr
	Comfort	Modern heating/cooling	0,2	per pers/yr
Clothing	Clothing	Clothing	1,3	kg/pers/yr
	Footwear	Shoes	0,45	kg/pers/yr
	Laundry	Laundry	59	kg/pers/yr
Health	Healthcare	Healthcare facility	0,25	m2/pers/yr
Education	Education	Equipped schools	1	m2/pers/yr
Communication & Information	Information access	TV / laptop, internet	0,2	per pers/yr
	Communication	Telephone/smartphone	0,2	per pers/yr
		ICT Infrastructure		Provided to all hh
Mobility	Mobility	Motorized transport	5000	pkm/pers/year

Appendix 4: Review of existing sharing

Table 9.4: Existing sharing principles used in PB-LCA

Equal Per Capita (EPC)	Capability to reduce	Historical debt
Grandfathering	Status Quo (SQ),	Land area
Economic/Gross Value Added (GVA)	Cost efficiency	Calorific content
Final Consumption Expenditure (FCE)	Physical production output	Ability to Pay
Green Incentive	Sovereignty	Social contribution
Resource efficiency	Basic Needs	Development Rights
Market shar	Consumer base	Voluntarism

Greenhouse Development Rights	Fulfilment of Human Needs	etc.

Source: Mentioned in text

Appendix 5: Sufficiency based sharing principles in Bai et al. (2024)

Table 9.5: Sufficiency-based sharing principles and two misleading sharing principles

	Article	Method of incorporating basic needs and/or sufficiency	Short explanation
1	**Bai et al. (2024)**	Review article. Identifies 13 studies that include "basic needs and preferences" (elaborated below in 1.1-1.13).	"Basic needs and preferences" is describes as "Shares are allocated such that fulfilment of human basic needs comes first, before distributing the rest of the resources to other non-basic needs."
1.1	**Chandrakumar et al. (2020)**	FCE	"Represents consumer preferences for different products and services"
1.2	**Perdomo Echenique et al. (2022)**	GVA, FCE	"Economic value, for example, has been considered as an aspect that contributes to human well-being. Previous PB-LCA studies have used gross value added (GVA) as an indicator to represent well-being generated from economic value added". "FCE refers to the consumers' preference to buying goods and services used to satisfy their individual needs."
1.3	**European Environment Agency et al. (2020)**	Include "needs" sharing principles like "equivalence between adults and children", "travel time to major cities", and "food nutrient adequacy"	"People have different resource needs due to e.g. age, household size or location. As a result, their right to resources could be differentiated according to population weighted by age".
1.4	**Sandin et al. (2015)**	Provides either same share, half the share of double the share (1, 0.5 or 2) to a given sector, based on its hypothetical contribution to fulfilling essential human needs such as clothes or shelter.	"It can be argued that market segments of high importance for essential human needs should have a right to a larger share of the allowed impact compared to their current share, and that less essential market segments, should have less of a right to cause impact". (Assumes how important a market segment is to fulfil human essential needs relative to the average market segment)
1.5	**Ryberg et al. (2018)**	FCE; GVA	GVA: Assuming that "economic value can be considered a proxy for contribution to human wellbeing". FCE: "Expresses consumer preferences for the activity under study. […] FCE is treated as a proxy for citizen preferences."
1.6	**Lucas et al. (2021)**	FCE	"Based on the contribution of the activity of interest to welfare and human wellbeing, based on economic value."
1.7	**Hjalsted et al. (2021)**	Sufficientarianism	"Sufficientarianism is unfeasible as an allocation principle in this study".
1.8	**Wheeler et al. (2021)**	FCE; SQ	"FCE reflects the consumers' preference for the product or activity".
1.9	**Brejnrod et al. (2017)**	FCE	"The more money a person spends […] the greater a share of the person's carrying capacity equivalent is allocated to the product or service
1.10	**Chandrakumar et al. (2019)**	Calorific Content	"Uses calories as a proxy to represent the fact that the primary purpose of agri-food production is to feed people".
1.11	**Bjørn et al. (2020)**	GVA	Not explicitly described

1.12	**Wolff et al. (2017)**	Consumer base	"Based on their contributions to meet human needs" reflects "equivalent number of persons fully fed by the company".
1.13	**Ryberg et al. (2021)**	Final consumption expenditure	"personal consumption can be considered as an indicator of human needs, that is, the functions we spend the most on are also the ones we need the most".
3	**van den Berg et al. (2020)**	i) Ability to Pay (emissions or budget allocated based on GDP per capita or average GDP per capita); ii) Greenhouse Development Right	i) Is about capability/need because it is based on the ability to bear the burdens ii) Is about capability/need because it safeguards people's right to reach a dignified level of sustainable human development. Uses a Responsibility-Capacity Index based on GDP/capita and income distribution.
4	**Ryberg (2018)**	Contribution to fulfilling essential human needs	Uses the method of Sandin et al. (2015) as explained above.
5	**Ryberg et al. (2020)**	Sufficientarianism	Sufficientarianism is mentioned, but the review finds no studies using sharing principle based on sufficientarianism

In the most recent review, Bai et al. (2024) identify 13 studies that apply "basic needs and preferences" sharing principles. However, when I investigate them, I see that they pool 'basic needs' and 'preferences' in the review. I find this unfortunate, since they represent two different underlying theoretical views and assumptions, as argued. Therefore, I investigated them all to distinguish between 'basic needs' sharing principles and usual 'preference' based sharing principles. This reveals that only four of them can be rightfully ascribed using a 'basic needs' sharing principle: Article 1.3, 1.4, 1.10, 1.13.

van den Berg et al., (2020) mention 'needs' as included in the 'Ability to Pay' and 'Greenhouse Development Right' sharing principles. However, since neither of these are referred to reflect sufficientarianism nor 'human basic needs' in other LCA literature and because both are based on GDP/capita, then I do not consider them relevant for 'basic human needs' in this thesis.

I will comment on two often used sharing principles because I see them as misleading in PB-LCA – Final Consumption Excpenditure (FCE) and Gross Value Added (GVA). Often, economic indicators are used for existing PB-LCA sharing principles under the assumption that "economic value can be considered a proxy for contribution to human wellbeing, i.e. increased economic value leading to increased wellbeing" (M. W. Ryberg et al., 2018). I will argue that they are misleading in reflecting contributions to human wellbeing and do not reflect the satisfaction of human needs. These sharing principles fall under a utilitarian ethical norm, not the sufficiency ethical norm, as I see it.

Final Consumption Expenditure (FCE) is one of those sharing principles, where the assigned share is proportional with consumers' final consumption expenditure for a good or service. A study highlights that the utilitarian perspective "advocates for a distribution based on the maximization of total utility" of consumers (M. W. Ryberg et al., 2020), the reason being that "from a utilitarian stand, the goal is to maximize the well-being of society" (ref) and "economic value has been considered an aspect that contributes to human well-being" (Perdomo Echenique et al., 2022).

Also, previous PB-LCA studies have used Gross Value Added (GVA) as an economic indicator, assumed to represent wellbeing generated from economic value added (Perdomo Echenique et al., 2022). In sum, I find it a misleading method to use utilitarian principles to reflect contributions to human wellbeing.

Appendix 6: Sufficiency sharing principles of Schlesier et al. (2024)

Table 9.6.1: Sufficiency sharing principle to 9 key resources

Ressource segment	CO_2 emissions	Global Warming Potential (100a)	Biodiversity loss	Ozone depletion potential	Phosphorus to soil	Phosphorus to ocean	reactive Nitrogen emissions	Land use	Cropland use	Blue water	Energy demand
Chemicals	9,2%	5,3%	1,8%	4,2%	0,2%	1,8%	3,1%	0,7%	0,3%	1,8%	2,5%
Metals	2,1%	12,4%	11,9%	4,2%	0,9%	0,6%	2,1%	7,9%	0,0%	2,2%	7,9%
Energy(carriers)	11,7%	10,0%	12,3%	2,9%	1,1%	0,6%	10,6%	7,8%	0,0%	13,2%	69,9%
Minerals	2,3%	1,1%	0,7%	0,3%	0,0%	0,0%	0,5%	0,4%	0,0%	0,4%	1,2%
Textiles	2,1%	2,0%	2,1%	4,4%	1,5%	3,9%	5,3%	1,3%	1,7%	9,1%	0,8%
Agrisector, animals	38,4%	18,5%	10,6%	10,1%	83,3%	7,7%	9,5%	6,4%	9,9%	4,1%	2,4%
Agrisector, plants	33,2%	48,6%	51,8%	72,4%	11,9%	84,6%	68,4%	60,8%	88,0%	68,7%	12,2%
Wood	0,1%	0,2%	7,8%	0,6%	0,1%	0,1%	0,0%	13,7%	0,0%	0,0%	1,5%
Water	1,0%	1,8%	1,0%	0,8%	1,1%	0,7%	0,4%	1,0%	0,0%	0,6%	1,7%
found shares	0,929	0,788	0,910	0,896	0,991	0,997	0,956	0,963	1,000	0,955	0,979

Table 9.6.2: Sufficiency sharing principle to 15 Decent Living Standard dimensions

	CO_2 emissions	Global Warming Potential (100a)	Biodiversity loss	Ozone depletion potential	Phosphorus to soil	Phosphorus to ocean	reactive Nitrogen emissions	Land use	Cropland use	Blue water	Energy demand
Food	66%	53%	57%	74%	94%	73%	74%	65%	98%	69%	14%
Cold storage	2%	1%	1%	0%	0%	0%	0%	0%	0%	0%	1%
Cooking	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Hygiene	2%	2%	2%	1%	0%	1%	1%	1%	0%	4%	2%
Building	2%	4%	10%	5%	0%	7%	3%	15%	0%	4%	19%
Final energy	3%	4%	5%	3%	0%	3%	1%	2%	0%	4%	20%
Light	1%	1%	1%	1%	1%	1%	2%	1%	0%	1%	3%
Comfort	8%	18%	8%	4%	1%	1%	2%	2%	0%	1%	4%
Clothing	4%	3%	3%	4%	2%	5%	9%	2%	2%	9%	2%
Healthcare	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Education	0%	0%	1%	1%	0%	1%	0%	2%	0%	0%	2%
Information	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Communication	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Assembly	1%	2%	2%	1%	0%	1%	1%	2%	0%	1%	3%
Mobility	8%	10%	10%	5%	1%	7%	5%	8%	0%	6%	30%

Appendix 7: Data sources to LCA of Danish household consumption

Table 9.7: Data of Danish annual household consumption

Consumption category	Data description	Number of goods	Year	Source
Food	Annual consumption of food in Denmark. Regionalized impact data	44	2021	EU Consumption Footprint (EU-JRC)
Food	Data on per food available for human consumption during the reference period in terms of quantity	39	2021	FAOSTAT (Food Supply Quantity)
Housing	Annual use of dwelling. Distinguished between house types (Single Family House and Multi Family House) and building age.	10	2021	EU Consumption Footprint (EU-JRC)

Housing (heat use)	Energy data on heat used in households by fuel type. Distinguished between house types (Single Family House and Multi Family House)	2	2022	The Danish Energy Agency
Housing (electricity)	Energy data on electricity use in households by energy sources. Distinguished between house types (Single Family House and Multi Family House)	2	2022	The Danish Energy Agency
Housing (water)	Household water use	1	2022	The Danish Energy Agency
Household appliances	Sales data on household appliance quantities, covering entire DK market	13	2022	Provided by APPLiA Denmark (Industrial assoc. for household appliances)
Household appliances	Annual use of household appliances. Regionalized impact data.	18	2021	EU Consumption Footprint (EU-JRC)
Household goods	Annual use of household goods. Regionalized impact data	36	2021	EU Consumption Footprint (EU-JRC)
Clothing and footwear	Energistyrelsen 2023 - Baggrundsnotat klimaaftryk af tekstilforbrug	5	2021	The Danish Energy Agency
Mobility	Total Danish fleet of passenger cars by car model per January 2024. I have calculated LCA of 90% of all models. Calculations then differentiated by fuel efficiency, weight, fuel type, main country of construction.	239	2023	Bilstatistik.dk (only allowed for use in this thesis)
Mobility	23 passenger car types, bus, air transport, train, two-wheelers	34	2021	EU Consumption Footprint (EU-JRC)
Mobility	Total passenger-km of national railway types, buses, motorcycles, bicycle/moped use, and ferry	12	2022	Statistics Denmark (PKM1; BANE21)
Mobility	All domestic scheduled flights from major Danish airports	17	2022	Statistics Denmark (FLYV33)
Mobility	All international scheduled flight departures from larger Danish airports to destination by country	139	2023	Provided by The Danish Civil Aviation and Railway Authority
Communi-cation	Number of all smartphones sold in Denmark 2023. 10 most sold smartphone models considered.	10	2023	Total Danish market data provided by Telenor. Only allowed for use in this thesis.
Recreation and culture	Hotel nights, hostel nights, and "vacation centres"	3	2023	Statistics Denmark (HOTEL2)
Mobility	Bicycle use	1	2022	Transportvaneundersøgelsen 2022
Total number of consumption goods considered		**625**		

Appendix 8: Environmental Footprint 3.1 LCIA method

Table 9.8.1: Impact categories of EF3.1

Impact category	Impact assessment model	Indicator unit	Source
Climate change	The Global Warming Potential (GWP) calculates the radiative forcing over a 100 year time horizon. It assesses the potential impact of different gaseous emissions on climate change.	kg CO_2 eq	IPCC 2021 + JRC adaptions
Ozone depletion	The Ozone Depletion Potential (ODP) calculates the destructive effects on the stratospheric ozone layer over a time horizon of 100 years. The stratospheric ozone layer reduces the amount of UV-radiation that reaches the ground, and which can cause damages for humans, animals, plants and materials.	kg CFC-11 eq	EDIP model based on the ODPs of WMO 2014 + integrations from other sources
Ionizing radiation	This category estimates the effect of radioactive emissions on human health. Most radiation stems from normal operation of nuclear power plants including the nuclear fuel production and treatment of radioactive wastes (accidents are not included). Quantification of the impact of ionizing radiation on the population is made with reference to Uranium 235.	kg U^{235} eq	Frischknecht et al. 2000
Photochemical ozone formation	This category calculates the effect of summer smog on human health. Ozone and other reactive oxygen compounds are formed as secondary contaminants in the troposphere (close to the ground). Ozone is formed by the oxidation of the primary contaminants VOC (Volatile Organic Compounds) or CO (carbon monoxide) in the presence of NOx (nitrogen oxides) under the influence of light. Expression of the potential contribution to photochemical ozone formation close to the ground. The method used includes spatial differentiation and is only valid for Europe. Considering a marginal increase in ozone formation, the LOTOS-EUROS spatially differentiated model averages over 14000 grid cells to define European factors.	kg NMVOC eq	Van Zelm et al. 2008 as applied in ReCiPe
Human toxicity, non-cancer	The unit "CTUh" (Comparative Toxic Unit for Humans) expresses the estimated increase in morbidity in the total human population due to different types of emissions entering into the environment. The calculation is based on USEtox® 2.1, which is a model that describes chemical fate, exposure, effect and optionally severity of emissions. No spatial differentiation beyond continent and world compartments. Specific groups of chemicals require further works (cf. details in other sections). Impact indicator: Comparative Toxic Unit for human (CTUh) expressing the estimated increase in morbidity in the total human population per unit mass of a chemical emitted (cases per kilogram).	CTUh	Fantke et al. 2017 Rosenbaum et al. 2008 as in Saouter et al. 2018
Human toxicity, cancer	Based on USEtox 2.1 model, see above	CTUh	Fantke et al. 2017 Rosenbaum et al. 2008 as in Saouter et al. 2018
Acidification	This impact category describes potential impacts on soil and freshwater that becomes more acid due to the deposition of certain pollutants from air: The "Accumulated Exceedance" model characterizes the change in critical load exceedance of the sensitive area in terrestrial and main freshwater ecosystems, to which acidifying substances deposit.	molc H+ eq	Posch et al. 2008 Seppälä et al. 2006
Particulate matter	This category estimates the potential effect of fine dust emissions on human health: The indicator is calculated applying the average slope between the Emission Response Function (ERF) working point and the theoretical minimum-risk level. Exposure model based on archetypes that include urban environments, rural environments, and indoor environments within urban and rural areas.	Disease incidence	Fantke et al. 2016
Eutrophication, freshwater	Expression of the degree to which the nutrients emitted in Europe reach the freshwater and lead to the problem of eutrophication. Only phosphorus emissions are evaluated since it is considered as the limiting factor in freshwater. EUTREND model used to model atmospheric emissions. Impact indicator: Phosphorus equivalents: European validity. Averaged characterization factors from country dependent characterization factors.	kg P eq	Struijs et al. 2009 as implemented in ReCiPe
Eutrophication, marine	Expression of the degree to which nutrients emitted in Europe reach the oceans and lead to eutrophication. Only nitrogen emissions evaluated since it is considered as the limiting factor in marine water. EUTREND model used to model atmospheric emissions. Impact indicator: Nitrogen equivalents.	kg N eq	Struijs et al. 2009 as implemented in ReCiPe
Eutrophication, terrestrial	Eutrophication means that too many nutrients reach ecosystems and harm the plants and animals living in sensitive systems: The "Accumulated Exceedance" model characterizes the change in critical load exceedance of the sensitive terrestrial area, to which eutrophying substances ("excess nutrients") deposit. It is European-country dependent which is not considered with the LCI data used in this study.	molc N eq	Posch et al. 2008 Seppälä et al. 2006
Ecotoxicity, freshwater	Measurement of environmental toxicity in freshwater due to emissions: The unit "CTUe" (Comparative Toxic Unit for ecosystems) is an expression of an estimate of the potentially affected fraction of species (PAF) integrated over time and volume per unit mass of a chemical emitted (PAF m3 year/kg). Specific groups of chemicals require further works. USEtox consensus model (multimedia model). No spatial differentiation beyond continent and world compartments. Specific groups of chemicals requires further works.	CTUe	Fantke et al. 2017 Rosenbaum et al. 2008 as in Saouter et al. 2018
Land use	Land use refers here to the amount and quality deficit of land occupied or transformed. This model is based on soil quality index as in LANCA model. CFs set was re-Calculated by JRC starting from LANCA® v 2.5 as baseline model. Out of 5 original indicators (Erosion resistance, Mechanical filtration, Physicochemical filtration, Groundwater regeneration, Biotic production) only 4 have been included in the aggregation (Physicochemical filtration was excluded due to the high correlation with the mechanical filtration). Biodiversity impacts are not covered in this method.[8]	Pt	De Laurentiis et al. 2019; Horn et al. 2018
Water use	Assessment of the water use related to local scarcity of water in different countries. Relative Available WAter REmaining (AWARE) per area in a watershed, after the demand of humans and aquatic ecosystems has been met.	m^3 deprived	Boulay et al. 2018
Resource use, fossils	Abiotic resource depletion fossil fuels (ADP-fossil); based on lower heating value	MJ eq	van Oers et al. 2002
Resource use, minerals and metals	Ultimate reserves model. The model takes both the annual production as well as the availability of the resource into account. (CML 2002 model). ADP for energy carriers, based on van Oers et al. 2002 as implemented in CML, v. 4.8 (2016). Depletion model based on use-to-availability ratio. Full substitution among fossil energy carriers is assumed.	kg Sb eq	van Oers et al. 2002

Source: Jungbluth (2024)

Table 9.8.2: Normalization and weighting factors in EF 3.1

Impact category	Normalization	Weighting
Climate change	0,0001324	21,1%
Ozone depletion	19,10	6,3%
Ionising radiation	0,000237	5,0%
Photochemical ozone formation	0,02447	4,8%
Particulate matter	1680	9,0%
Human toxicity, non-cancer	7768	1,8%
Human toxicity, cancer	57961	2,1%
Acidification	0,018	6,2%
Eutrophication, freshwater	0,6223	2,8%
Eutrophication, marine	0,05116	3,0%
Eutrophication, terrestrial	0,005658	3,7%
Ecotoxicity, freshwater	0,00001763	1,9%
Land use	0,00000122	7,9%
Water use	0,00008719	8,5%
Resource use, fossils	0,00001538	8,3%
Resource use, minerals and metals	15,72	7,6%

Appendix 9: Environmental impact of all household consumption goods

Table 9.9: Environmental impact of 624 Danish consumption goods, total impact, single weighted score

	Single weighted score
Impact unit	Points
Beef meat	1154941
Bovine Meat	659423
Milk - Excluding Butter	643466
Passenger car (ALL gasoline)	560959
Heat, SFH, household use	468805
Pig meat	466503
Cheese	379599
Passenger car (ALL diesel)	240714
Washing machine	238722
Single family house (moderate, before 1945)	234411
Pigmeat	217837
Single family house (moderate, 1945-1969)	197824
Electricity, SFH, low voltage, household use	188794
Single family house (moderate, 1970-1989)	183549
Heat, MFH, household use	183205
Potatoes	180700
Bedroom furniture	179109
Vaskemaskine	171788
Butter	164678
Poultry meat	145309
Nuts and products	125617
Køl & kølfrys	119635
Passenger car (gasoline, small, <EUR4)	116615
Wine	108935
Beer	105999
Tørretumbler	103732
Tumble dryer	101718
Kitchen furniture	101280
Bus	101145
Multi family house (moderate, 1945-1969)	98499
Wheat and products	96431
Laptop	95757
T-shirt	90630
Toilet paper	89875
Passenger car (gasoline, medium, <EUR4)	89184
Dishwasher (large)	87655
Milk	83472
Coffee and products	81712
Passenger car (gasoline, small, EUR6)	81537
Passenger car (diesel, medium, <EUR4)	81227
Jeans	78699
Electricity, MFH, low voltage, household use	71693
Sugar (Raw Equivalent)	71230
Single family house (moderate, after 2010)	68594
Coffee	66355
Cod	64610
Multi family house (moderate, 1970-1989)	63724
Single family house (moderate, 1990-2010)	62998
Passenger car (gasoline, medium, EUR6)	62907
Chocolate	60011
Passenger car (gasoline, small, EUR5)	54931
Air transport (continental)	54726
TV	53046
Jeans	52972
Multi family house (moderate, before 1945)	52773
Butter, Ghee	51619
Eggs	51470
Poultry Meat	50064
Passenger car (diesel, medium, EUR6)	49771
Hotel	46593
Bed mattresses	46078
Passenger car (gasoline, medium, EUR5)	42384
Passenger car (gasoline, small, EUR4)	41066
Passenger car (hybrid)	40406
T-shirt	40096
Sugar	37815
Cocoa Beans and products	37577
Passenger car (diesel, medium, EUR5)	36726
Feriecentre	35933
Kogesektion	35136
Oven	35075
Palm oil	34533
Broccoli	33659
Newsprint	33274
Oilcrops Oil, Other	32852
Vegetables, other	32628
Fridge	32569
Potatoes and products	31781
Passenger car (gasoline, medium, EUR4)	31475
Tuna (canned)	31336
Plastic household articles	31329
Bread	30815
Multi family house (moderate, 1990-2010)	30634
Passenger car (electric)	29367
Passenger car (ALL electric)	29367
Mobile phone	28497
Volkswagen Golf	28182
Passenger car (diesel, medium, EUR4)	27959
Jakke	27701
Olive oil	27164
Oranges	26859
Volkswagen up!	26798
Toyota Yaris	26261
Fruits, other	26119
Air transport (intercontinental)	25945
Toyota Aygo	25830
Peugeot 208	25694
Shrimp	25566
Tomatoes	25428
Salmon	25190
Hostel	24951
Floor care, all	24854
Bus (Interurban)	23651
Volkswagen Polo	22731
Upholstered seat	22523
Train, National	21507
Tomatoes and products	20701
Skoda Octavia	20551
Renault Clio	20230
Powder laundry detergent	20016
Skoda Fabia	19957
Rice	19860
Liquid laundry detergent	19616
Ford Fiesta	19281
Opel Corsa	19214
Citroen C3	19099
Nissan Qashqai	18763
Sunflower oil	18682
Passenger car (diesel, large, <EUR4)	18522
Train (electric)	17793
Volkswagen Passat	17381
Multi family house (moderate, after 2010)	17289
KOBENHAVN TO UNITED STATES, SCHEDULED	17059
Fluorescent	17050
Non-upholstered seat	16918
Almonds	16834
Bus (Urban, standard)	16567
Citroen C1	16450
Carrot	16443
Bananas	16296
Book	16275
Passenger car (gasoline, large, <EUR4)	16027
Dishwasher detergent	15879
LED	15746
Vacuum cleaner	15573
Kia Picanto	15506
Two-wheelers (large)	15470
Pelagic Fish	15178
Rice and products	15124
Oranges, Mandarines	15005
Work and Waterproof footwear	14675
Mercedes-Benz C-Klasse	14564
Dishwasher (small)	13906
Cream	13757
Sanitary pad	13306
Ford Focus	13291
Blouse	13198
Hyundai I10	13165
All-Purpose cleaner	13002
Opel Astra	12977
Air conditioner	12954
Rye and products	12511
Suzuki Swift	12495
Rapeseed oil	12191
Apples	12123
BMW 3'er	12079
Volkswagen Touran	11904
Hyundai I20	11737
Passenger car (diesel, large, EUR6)	11665

Passenger car (gasoline, large, EUR6)	11433
Kia Ceed	11288
Apples and products	11124
Bar soap	10791
KOBENHAVN TO SPAIN, SCHEDULED	10749
Tesla Model 3	10727
Peugeot 308	10649
Toyota Avensis	10461
Mercedes-Benz E-Klasse	10335
Fiat 500	10036
Tesla Model Y	10006
Ford Kuga	9976
Trouser	9837
Ford Mondeo	9546
Renault Captur	9491
Hyundai I30	9439
Skoda Citigo	9417
Audi A3	9325
Kia Rio	9136
Peugeot 107	9093
Mikrobølgeovn	9032
Peugeot 2008	9015
Audi A4	8975
Renault Megane	8869
Pre-prepared meals	8733
Toys	8727
BMW 5'er	8702
Fashion footwear	8472
Passenger car (diesel, large, EUR5)	8460
Plastic articles (apparel)	8397
Wooden table	8236
Tea (including mate)	8103
Kjole	8069
Strawberry	8031
Pasta	8008
Kaffemaskine, filter	7956
Suzuki SX4	7810
Toyota Auris	7781
Passenger car (gasoline, large, EUR5)	7704
Audi A6	7654
Peugeot 206	7517
Oats	7264
Biscuits	7177
Leisure footwear	6926
Toyota Corolla	6889
Bananas	6858
Peugeot 3008	6815
Demersal Fish	6706
Peugeot 207	6653
Mazda 2	6566
Citroen C4	6558
Kaffe, pod og kapsel	6535
Seat Ibiza	6385
Passenger car (diesel, large, EUR4)	6384
Sports footwear	6334
KOBENHAVN TO UNITED KINGDOM, SCHEDULI	6290
Mercedes-Benz A-Klasse	6124
Tampon	6124
Fish, Body Oil	6055
Sokker	5903
Ford S-Max	5851
Volkswagen Tiguan	5732
Seat Leon	5717
Passenger car (gasoline, large, EUR4)	5696
Chevrolet Spark	5662
Ford Ka	5610
Fiat Punto	5574
Volvo XC60	5550
KOBENHAVN TO ITALY, SCHEDULED	5547
Volkswagen T-Roc	5493
Two-wheelers (medium)	5410
Mutton & Goat Meat	5408
Suzuki Ignis	5366
Beans	5241
Taxi	5234
KOBENHAVN TO THAILAND, SCHEDULED	5180
Suzuki Vitara	5146
Volvo V70	5067
Ford C-Max	5062
Hyundai Kona	5005

Mazda 6	4987
Volkswagen ID.4	4932
Mazda 3	4895
Peugeot 108	4884
KOBENHAVN TO TURKEY, SCHEDULED	4835
Skoda Enyaq iV	4781
Volvo V60	4715
Seat Mii	4492
Tea	4467
Suzuki Alto	4285
Nissan Micra	4261
Fiat Panda	4256
Mineral water	4251
Citroen Grand C4 Picasso	4227
BMW 1'er	4151
Skoda Superb	4101
Volvo XC40	4081
Audi Q5	4076
KOBENHAVN TO FRANCE, SCHEDULED	3995
Opel Insignia	3949
Toyota RAV4	3778
Ferry "Molslinjen", Odden-Aarhus	3741
Suzuki Splash	3680
Avocado	3629
KOBENHAVN TO UNITED ARAB EMIRATES, SCH	3620
Bicycle	3527
Volkswagen T-Cross	3502
Audi Q4 e-tron	3492
Honda Civic	3470
Opel Karl	3440
KOBENHAVN TO NORWAY, SCHEDULED	3387
Citroen Berlingo	3383
Renault Twingo	3333
Suzuki Baleno	3268
Mazda CX-5	3237
KOBENHAVN TO PORTUGAL (MADEIRA AND A	3236
KOBENHAVN TO QATAR, SCHEDULED	3235
Grapes and products (excl wine)	3230
Mitsubishi Space Star	3230
Renault Grand Scenic	3200
Shampoo	3139
Citroen C4 Cactus	3128
Kia Niro	3116
Hand dishwashing detergent	3106
Mercedes-Benz B-Klasse	3103
Ford Transit Custom	3081
KOBENHAVN TO ICELAND, SCHEDULED	3063
Cashew	3048
Peugeot 307	3038
KOBENHAVN TO SINGAPORE, SCHEDULED	3030
KOBENHAVN TO GERMANY, SCHEDULED	3022
Onions	2996
Toyota Verso	2966
Suzuki Celerio	2915
Toyota C-HR	2914
Hair conditioner	2875
Mitsubishi Colt	2871
Nissan Note	2839
Hyundai Tucson	2821
Volkswagen ID.3	2802
Hyundai Getz	2721
Train, International	2702
Dacia Duster	2699
Mini 3-dørs	2638
Liquid soap	2635
Renault Kadjar	2630
Audi A5	2627
Audi Q2	2626
Suzuki Liana	2545
KOBENHAVN TO CANADA, SCHEDULED	2536
Audi Q3	2528
Train (diesel)	2472
Volvo V40	2439
BMW X1	2415
Skoda Kamiq	2380
BMW X5	2378
Polestar 2	2363
Peugeot 508	2348
Toyota Aygo X	2346
KOBENHAVN TO NETHERLANDS, SCHEDULED	2343

Citroen C5	2331
Volvo V50	2325
Chevrolet Aveo	2311
Peas	2310
Peugeot 5008	2303
BILLUND TO SPAIN, SCHEDULED	2296
Ford Mustang	2277
Volkswagen Caddy	2250
Honda Jazz	2248
Opel Meriva	2246
Mercedes-Benz GLC	2180
Ford Mustang Mach-E	2173
Pineapples and products	2168
Maize and products	2165
Air transport (national)	2160
KOBENHAVN TO SWEDEN, SCHEDULED	2159
Skoda Rapid	2154
Toyota Yaris Cross	2149
Opel Crossland X	2142
Coffee maker	2128
Kia Sportage	2074
Citroen C3 Picasso	2070
Honda CR-V	2067
Renault Zoe	2036
Dacia Sandero	1976
Mazda CX-3	1968
Peugeot 407	1965
KOBENHAVN TO CHINA, SCHEDULED	1958
Dacia Logan MCV	1946
Tesla Model S	1941
KOBENHAVN TO GREECE, SCHEDULED	1939
Urban train	1894
BMW iX3	1857
Kaffe fuldaut. Espresso	1847
Lemons, Limes and products	1805
Citroen C4 Picasso	1801
BMW 4'er	1770
Saab 9-3	1767
Opel Zafira	1767
Flight, domestic	1765
Opel Vectra	1764
BMW 2'er	1751
BMW X3	1749
Mercedes-Benz GLE	1744
Mercedes-Benz CLA	1738
Mercedes-Benz EQA	1734
Skoda Kodiaq	1731
KOBENHAVN TO SWITZERLAND, SCHEDULED	1726
Citroen C5 Aircross	1722
Olives (including preserved)	1709
Volkswagen ID.5	1664
Porsche 911	1660
Opel Grandland X	1659
Volvo XC90	1652
Opel Mokka	1599
Cupra Born	1595
Seat Arona	1594
Volkswagen Fox	1593
Skoda Karoq	1588
Nissan Juke	1557
KOBENHAVN TO POLAND, SCHEDULED	1557
Audi e-tron	1542
DS 3	1540
Færgeruter i alt, ekskl. Molslinjen	1524
Seat Toledo	1522
Volvo V90	1500
Renault Megane E-Tech	1484
Renault Scenic	1470
Mercedes-Benz GLA	1450
Mercedes-Benz GLB	1434
Citroen C3 Aircross	1422
Mercedes-Benz EQB	1398
Audi A1	1387
Skoda Scala	1384
Hyundai Ioniq 5	1384
Volvo S60	1380
Dacia Lodgy	1377
KOBENHAVN TO FINLAND, SCHEDULED	1376
Mazda CX-30	1366
Audi Q7	1353

KOBENHAVN TO GREENLAND, SCHEDULED	1323
Ford Galaxy	1323
BMW i4	1276
Nissan Leaf	1271
Mercedes-Benz Sprinter	1248
Mitsubishi ASX	1245
KOBENHAVN TO AUSTRIA, SCHEDULED	1240
Mercedes-Benz M-Klasse	1221
Kia XCeed	1215
Kia Venga	1209
Kia Optima	1196
Tofu	1195
MG EHS	1174
BILLUND TO UNITED KINGDOM, SCHEDULED	1143
Suzuki Wagon R	1137
Lentils	1133
Volkswagen Golf Plus	1124
Mazda MX-5	1122
Kia EV6	1121
Hyundai Ioniq	1109
Mercedes-Benz SLK	1108
BILLUND TO ITALY, SCHEDULED	1079
Mitsubishi Outlander	1044
Mercedes-Benz EQC	1009
Plastic furniture	1003
KOBENHAVN TO JAPAN, SCHEDULED	1002
BMW I3	938
Porsche Cayenne	932
Volkswagen Sharan	931
Metro	888
Breast pad	857
Flight, København To Aalborg	849
KOBENHAVN TO INDIA, SCHEDULED	838
Flight, Aalborg To København	836
Spices, Other	834
KOBENHAVN TO IRELAND, SCHEDULED	829
KOBENHAVN TO BELGIUM, SCHEDULED	805
Mercedes-Benz EQE	707
BILLUND TO NETHERLANDS, SCHEDULED	701
BILLUND TO TURKEY, SCHEDULED	668
KOBENHAVN TO EGYPT, SCHEDULED	650
Soy beverage	642
KOBENHAVN TO HUNGARY, SCHEDULED	633
Smart Fortwo	589
Mercedes-Benz S-Klasse	585
KOBENHAVN TO CROATIA, SCHEDULED	568
BILLUND TO GERMANY, SCHEDULED	552
Porsche Macan	548
KOBENHAVN TO ROMANIA, SCHEDULED	542
Scooter 45	542
KOBENHAVN TO LITHUANIA, SCHEDULED	542
Hair dryer	531
BMW iX1	497
KOBENHAVN TO CYPRUS, SCHEDULED	496
Iphone 14 Pro Max	494
KOBENHAVN TO CZECH REPUBLIC, SCHEDULE	484
Xpeng G9	484
Porsche Panamera	483
AALBORG TO SPAIN, SCHEDULED	483
Mazda MX-30	482
BILLUND TO POLAND, SCHEDULED	472
Iphone 15 Pro Max	471
BILLUND TO ROMANIA, SCHEDULED	461
Samsung Galaxy A14 4G	451
Rape and Mustardseed	439
Samsung Galaxy A54 5G	429
Two-wheelers (small)	421
Iphone 14 Pro	408
Samsung Galaxy A14 5G	408
Porsche Boxster	405
Tesla Model X	403
KOBENHAVN TO LEBANON, SCHEDULED	398
Iphone 14	395
KOBENHAVN TO LATVIA, SCHEDULED	389
BILLUND TO FRANCE, SCHEDULED	370
AALBORG TO NETHERLANDS, SCHEDULED	355
KOBENHAVN TO SERBIA, SCHEDULED	338
Chickpeas	331
Iphone 13	314
KOBENHAVN TO BULGARIA, SCHEDULED	307

Grapefruit and products	307
BILLUND TO PORTUGAL (MADEIRA AND AZOR	301
Iphone 15 Pro	290
AARHUS TO SPAIN, SCHEDULED	281
BMW i5	275
BILLUND TO GREECE, SCHEDULED	266
AARHUS TO UNITED KINGDOM, SCHEDULED	262
BILLUND TO MALTA, SCHEDULED	257
BILLUND TO NORWAY, SCHEDULED	255
KOBENHAVN TO MOROCCO, SCHEDULED	251
KOBENHAVN TO ISRAEL, SCHEDULED	247
Iphone 15	231
KOBENHAVN TO IRAQ, SCHEDULED	230
KOBENHAVN TO THE REPUBLIC OF NORTH MA	227
AARHUS TO PORTUGAL (MADEIRA AND AZORI	216
Quinoa	205
Quinoa	205
AALBORG TO UNITED STATES, SCHEDULED	204
Sandals	193
BILLUND TO HUNGARY, SCHEDULED	186
BILLUND TO ICELAND, SCHEDULED	167
Halogen main voltage	165
BILLUND TO IRELAND, SCHEDULED	164
Aquatic Animals, Others	159
Jaguar I-Pace	150
Fisker Ocean	149
Bus (Urban, CNG)	140
AALBORG TO TURKEY, SCHEDULED	135
KOBENHAVN TO ESTONIA, SCHEDULED	133
Letbane	131
BILLUND TO AUSTRIA, SCHEDULED	127
Flight, København To Bornholm	117
BILLUND TO BELGIUM, SCHEDULED	117
Flight, Aarhus To København	108
Flight, Bornholm To København	107
AARHUS TO ROMANIA, SCHEDULED	106
Porsche 944	106
BILLUND TO LATVIA, SCHEDULED	105
Porsche Cayman	104
Flight, København To Aarhus	102
KOBENHAVN TO LUXEMBOURG, SCHEDULED	101
AARHUS TO EGYPT, SCHEDULED	100
AALBORG TO UNITED KINGDOM, SCHEDULED	96
Tap water, household use	85
Dodge Challenger	83
Dodge Charger	82
AARHUS TO ITALY, SCHEDULED	81
Bentley Continental	79
BILLUND TO SWEDEN, SCHEDULED	78
Rolls-Royce	71
AARHUS TO POLAND, SCHEDULED	71
BILLUND TO GREENLAND, SCHEDULED	68
BILLUND TO LITHUANIA, SCHEDULED	61
Maserati Levante	59
Hair-related products	57
AALBORG TO LITHUANIA, SCHEDULED	52
Xpeng P7	52
KOBENHAVN TO JORDAN, SCHEDULED	52
Ferrari 308	51
AARHUS TO LATVIA, SCHEDULED	48
Mercedes-Benz EQS SUV	48
AALBORG TO ICELAND, SCHEDULED	48
KOBENHAVN TO MONTENEGRO, SCHEDULED	47
Sleeping bag	46
BILLUND TO BOSNIA AND HERZEGOVINA, SCH	43
Bentley Continental GT	43
AALBORG TO NORWAY, SCHEDULED	34
Flight, Sønderborg To København	34
Rolls-Royce Silver Shadow	34
ESBJERG TO UNITED KINGDOM, SCHEDULED	34
Lamborghini Urus	33
KOBENHAVN TO MALTA, SCHEDULED	33
Flight, Karup To København	33
Flight, København To Sønderborg	32
AALBORG TO ITALY, SCHEDULED	31
Maserati Quattroporte	31
Flight, København To Karup	31
AARHUS TO NORWAY, SCHEDULED	30
AARHUS TO GREECE, SCHEDULED	30
Halogen low voltage	29

Porsche Carrera	28
BILLUND TO FINLAND, SCHEDULED	27
Marine Fish, Other	27
AARHUS TO CROATIA, SCHEDULED	23
AARHUS TO SWEDEN, SCHEDULED	23
Flight, Billund To Bornholm	22
Maserati GranCabrio	21
Flight, Bornholm To Billund	19
Flight, Billund To København	18
Aston Martin Vantage	16
Ferrari California	14
AARHUS TO NETHERLANDS, SCHEDULED	14
Flight, Aalborg To Bornholm	13
Flight, Bornholm To Aalborg	13
KOBENHAVN TO SLOVAKIA, SCHEDULED	13
KOBENHAVN TO THAILAND, ANDEN FLYVNIN	13
Ferrari 488	13
KOBENHAVN TO GEORGIA, SCHEDULED	13
BILLUND TO SWITZERLAND, SCHEDULED	13
Lamborghini Huracan	12
KOBENHAVN TO SPAIN, ANDEN FLYVNING	12
Ferrari Portofino	12
KOBENHAVN TO CUBA, SCHEDULED	12
BILLUND TO ESTONIA, SCHEDULED	11
KOBENHAVN TO ALBANIA, SCHEDULED	10
Flight, København To Billund	10
BILLUND TO UNITED STATES, ANDEN FLYVNIN	8.3
KOBENHAVN TO INDIA, ANDEN FLYVNING	8.0
KOBENHAVN TO QATAR, ANDEN FLYVNING	6.8
ESBJERG TO NORWAY, SCHEDULED	5.7
Flight, Bornholm To Sønderborg	5.4
KOBENHAVN TO GREECE, ANDEN FLYVNING	3.9
BILLUND TO CYPRUS, SCHEDULED	2.7
KOBENHAVN TO CYPRUS, ANDEN FLYVNING	2.7
BILLUND TO EGYPT, SCHEDULED	2.4
KOBENHAVN TO SWEDEN, ANDEN FLYVNING	2.4
KOBENHAVN TO NORWAY, ANDEN FLYVNING	2.4
BILLUND TO UNITED KINGDOM, ANDEN FLYVN	2.3
AALBORG TO SWEDEN, SCHEDULED	2.1
ROSKILDE TO GERMANY, ANDEN FLYVNING	2.1
AALBORG TO CYPRUS, ANDEN FLYVNING	2.1
KOBENHAVN TO TURKEY, ANDEN FLYVNING	2.0
Passenger car (LPG)	2.0
KOBENHAVN TO ITALY, ANDEN FLYVNING	1.8
ESBJERG TO BOSNIA AND HERZEGOVINA, SCHE	1.6
BILLUND TO SPAIN, ANDEN FLYVNING	1.4
ROSKILDE TO SWEDEN, ANDEN FLYVNING	1.4
BILLUND TO ROMANIA, ANDEN FLYVNING	1.3
KOBENHAVN TO UNITED STATES, ANDEN FLY	1.3
BILLUND TO FRANCE, ANDEN FLYVNING	1.1
BILLUND TO ITALY, ANDEN FLYVNING	1.0
ROSKILDE TO FRANCE, ANDEN FLYVNING	1.0
AALBORG TO GREENLAND, SCHEDULED	1.0
BILLUND TO POLAND, ANDEN FLYVNING	0.9
BILLUND TO SWEDEN, ANDEN FLYVNING	0.9
KOBENHAVN TO NETHERLANDS, ANDEN FLYV	0.9
BILLUND TO SWITZERLAND, ANDEN FLYVNING	0.8
BORNHOLM/RONNE TO GERMANY, ANDEN FLY	0.8
KOBENHAVN TO AUSTRIA, ANDEN FLYVNING	0.7
BORNHOLM/RONNE TO SWEDEN, ANDEN FLYV	0.7
ROSKILDE TO UNITED KINGDOM, ANDEN FLYV	0.7
BILLUND TO GREECE, ANDEN FLYVNING	0.7
SONDERBORG TO UNITED KINGDOM, SCHEDUL	0.6
BORNHOLM/RONNE TO POLAND, ANDEN FLYV	0.5
Incasdescent bulb	-13.4
Beans	-0.1

Appendix 10: Elasticity estimates of 291 consumption goods

I have colour-scaled the elasticity estimates so all red cells reflect a high degree of luxury.

FOOD AND NON-ALCOHOLIC BEVERAGES	0,25
Rice	0,37
Flours and other cereals	-0,64
Bread	0,58
Other bakery products	0,11
Pizza and quiche	0,16
Pasta products and couscous	0,55
Breakfast cereals	0,73
Other cereal products	-0,25
Beef and veal	-0,03
Pork	0,03
Lamb and goat	2,07
Poultry	1,11
Other meats	0,00
Edible offal	-0,15
Dried, salted or smoked meat	0,18
Other meat preparations	0,77
Fresh or chilled fish	0,72
Frozen fish	-0,17
Fresh or chilled seafood	2,10
Frozen seafood	-2,05
Dried, smoked or salted fish and seafood	0,20
Other preserved or processed fish and seafood prep.	0,57
Milk, whole, fresh	0,00
Milk, low fat, fresh	0,77
Milk, preserved	0,00
Yoghurt	0,22
Cheese and curd	-0,09
Other milk products	0,08
Eggs	0,07
Butter	-0,02
Margarine and other vegetable fats	0,39
Olive oil	-0,87
Other edible oils	1,08
Other edible animal fats	0,00
Fresh or chilled fruit	-0,02
Frozen fruit	1,83
Dried fruit and nuts	0,21
Preserved fruit and fruit-based products	-0,65
Fresh or chilled vegetables (not potatoes) and other tubers	-0,08
Frozen vegetables other than potatoes and other tubers	-0,21
Dried vegetables, other preserved or processed vegetables	0,51
Potatoes	-0,02
Crisps	0,56
Other tubers and products of tuber vegetables	0,00
Sugar	0,37
Jams, marmalades and honey	-0,04
Chocolate	0,51
Confectionery products	0,07
Edible ices and ice cream	-0,19
Artificial sugar substitutes	1,54
Sauces, condiments	0,35
Salt, spices and culinary herbs	0,28
Baby food	0,32
Ready-made meals	0,00
Other food products n.e.c.	-0,30
Coffee	0,18
Tea	-0,52
Cocoa and powdered chocolate	0,51
Mineral or spring waters	-0,80
Soft drinks	0,00
Fruit and vegetable juices	0,25

ALCOHOLIC BEVERAGES, TOBACCO AND NARCOTICS	0,30
Spirits and liqueurs	1,03
Alcoholic soft drinks	1,75
Wine from grapes	-0,71
Wine from other fruits	3,08
Fortified wines	3,16
Wine-based drinks	4,55
Lager beer	1,12
Other alcoholic beer	-2,16
Low and non-alcoholic beer	0,00
Cigarettes	1,20
Cigars	-1,64
Other tobacco products	-0,19

HOUSING, WATER, ELECTRICITY, GAS, AND OTHER FUELS	0,49
Actual rentals paid by tenants	-0,11
Actual rentals paid by tenants for secondary residences	1,88
Imputed rentals of owner-occupiers	0,62
Other imputed rentals	0,64
Materials for the maintenance and repair of the dwelling	0,01
Services of plumbers	3,79
Services of electricians	3,38
Maintenance services for heating systems	0,73
Other services for maintenance and repair of the dwelling	1,55
Water supply	-0,93
Refuse collection	-1,22
Sewage collection	0,18
Security services	-4,08
Other services related to dwelling	0,09
Electricity	0,64
Natural gas and town gas	1,45
Liquefied hydrocarbons (butane, propane, etc.)	1,45
Liquid fuels	-0,23
Coal	-0,47
Other solid fuels	0,90
Heat energy	1,39

FURNISHING, HOUSEHOLD EQUIPMENT AND -MAINTENANCE	0,82
Household furniture	1,38
Garden furniture	-0,66
Lighting equipment	0,64
Other furniture and furnishings	1,08
Carpets and rugs	0,30
Other floor coverings	2,18
Services of laying of fitted carpets and floor coverings	-0,11
Repair of furniture, furnishings and floor coverings	-0,39
Furnishing fabrics and curtains	-1,50
Bed linen	0,68
Table linen and bathroom linen	2,00
Other household textiles	2,23
Refrigerators, freezers and fridge-freezers	-0,97
Clothes washing- & drying machine, and dishwashing machine	0,52
Cookers	-0,08
Heaters, air conditioners	0,75
Cleaning equipment	0,36
Other major household appliances	-1,64
Food processing appliances	-5,64
Coffee machines, tea makers and similar appliances	-1,18
Irons	-4,54
Toasters and grills	0,00
Other small electric household appliances	1,46
Repair of household appliances	0,45
Glassware, crystal-ware, ceramic ware and chinaware	-1,21
Cutlery, flatware and silverware	1,34
Non-electric kitchen utensils and articles	0,48
Motorized major tools and equipment	0,58
Repair, leasing and rental of major tools and equipment	-2,84
Non-motorized small tools	1,04
Miscellaneous small tool accessories	1,56
Repair of non-motorized small tools and misc. accessories	-0,36
Cleaning and maintenance products	0,13
Other non-durable small household articles	0,96
Domestic services by paid staff	0,52
Hire of furniture and furnishings	2,23
Other domestic services and household services	1,51

Table 9.10 (1/2): Elasticity estimates of Danish household consumption goods, 1994-2022 median, by ECOICOP-5

TRANSPORT	1,49
New motor cars	1,42
Second-hand motor cars	2,17
Motor cycles	3,53
Bicycles	-1,30
Tyres	2,44
Spare parts for personal transport equipment	-1,20
Accessories for personal transport equipment	-6,27
Diesel	0,66
Petrol	1,16
Lubricants	1,15
Maintenance and repair of personal transport equipment	0,94
Hire of garages, parking spaces and personal transport equipment	0,44
Toll facilities and parking meters	0,74
Driving lessons, tests, licences and road worthiness tests	0,38
Passenger transport by train	4,71
Passenger transport by bus and coach	4,35
Passenger transport by taxi and hired car with driver	0,81
Domestic flights	8,47
International flights	0,93
Passenger transport by sea	0,68
Combined passenger transport	0,95
Removal and storage services	5,71
Other purchased transport services n.e.c.	2,95

COMMUNICATION	0,28
Letter handling services	0,52
Fixed telephone and equipment	0,00
Mobile telephone and equipment	0,83
Repair of telephone or telefax equipment	9,84
Wired telephone services	0,23
Wireless telephone services	-2,53
Internet access provision services	-5,44
Bundled telecommunication services	3,81

EDUCATION	0,93
Primary education	0,50
Secondary education	4,99
Tertiary education	-1,27
Education not definable by level	2,36

RESTAURANTS AND HOTELS	1,57
Restaurants, cafés and dancing establishments	1,86
Fast food and take away food services	2,88
Canteens	2,02
Hotels, motels, inns and similar accommodation services	3,18
Holiday centres, camping sites, youth hostels and similar accom.	0,53
Accommodation services of other establishments	6,35

MISCELLANEOUS GOODS AND SERVICES	1,55
Travel goods	0,97
Articles for babies	0,67
Repair of other personal effects	0,00
Other personal effects n.e.c.	1,09
Child care services	0,86
Services to maintain people in their private homes	-3,45
Life insurance	3,53
Insurance connected with the dwelling	0,79
Private insurance connected with health	0,97
Motor vehicle insurance	0,77
Travel insurance	1,37
Other insurance	2,34
Charges by banks etc.	2,23
Fees and service charges of brokers, investment counsellors	-1,05
Administrative fees	-0,25
Legal services and accountancy	-0,56
Funeral services	-5,90
Other fees and services	-2,93

HEALTH	0,81
Pharmaceutical products	0,10
Pregnancy tests and mechanical contraceptive devices	2,18
Other medical products n.e.c.	1,80
Corrective eye-glasses and contact lenses	1,59
Repair of therapeutic appliances and equipment	-8,14
Other therapeutic appliances and equipment	3,91
General practice	0,31
Specialist practice	-1,00
Dental services	0,15
Other paramedical services	-0,38
Hospital services	3,37

CLOTHING AND FOOTWEAR	1,53
Clothing materials	-0,53
Garments for men	0,63
Garments for women	1,33
Garments for infants (0-2 years) and children (3-13 years)	2,20
Other articles of clothing	2,36
Clothing accessories	0,61
Cleaning of clothing	-1,16
Repair and hire of clothing	0,00
Footwear for men	3,58
Footwear for women	1,38
Footwear for infants and children	3,57
Repair and hire of footwear	5,11
Hairdressing for men and children	2,01
Hairdressing for women	0,29
Personal grooming treatments	1,96
Electric appliances for personal care	-0,50
Repair of electric appliances for personal care	0,36
Non-electrical appliances	2,43
Hygiene and wellness, esoteric- and beauty products	1,19
Jewellery	0,70
Clocks and watches	2,06
Repair of jewellery, clocks and watches	0,58

RECREATION AND CULTURE	1,46
Equipment for the reception, recording and reproduction of sound	1,83
Equipment for recording and reproduction of sound and vision	-0,21
Other equipment for recording and reproduction of sound and picture	0,92
Cameras	2,39
Optical instruments	0,00
Personal computers	2,37
Accessories for information processing equipment	2,65
Software	-3,33
Calculators and other information processing equipment	3,33
Pre-recorded recording media	1,69
Unrecorded recording media	-21,60
Other recording media	0,00
Repair of audiovisual, photographic and info-processing equipment	2,52
Camper vans, caravans and trailers	-2,19
Boats, outboard motors and fitting out of boats	0,45
Horses, ponies and accessories	6,80
Major items for games and sport	-6,05
Musical instruments	-0,47
Maintenance and repair of other major durables	3,62
Games and hobbies	-0,85
Toys and celebration articles	0,89
Equipment for sport	-4,20
Equipment for camping and open-air recreation	2,31
Repair of equipment for sport, camping and open-air recreation	8,54
Garden products	-2,22
Plants and flowers	0,81
Purchase of pets	0,27
Products for pets	-0,21
Veterinary and other services for pets	0,15
Recreational and sporting services - Attendance	1,98
Recreational and sporting services - Participation	0,52
Cinemas, theatres, concerts	-0,35
Museums, zoological gardens etc.	2,22
Television and radio licence fees, subscriptions	1,07
Hire of equipment and accessories for culture	1,97
Photographic services	0,63
Games of chance	2,45
Fiction books	2,20
Educational text books	1,10
Other non-fiction books	1,33
Newspapers	0,78
Magazines and periodicals	1,73
Miscellaneous printed matter	-1,94
Paper products	0,68
Other stationery and drawing materials	1,20
Package domestic holidays	-3,25
Package international holidays	2,50

Table 9.10 (2/2): Elasticity estimates of Danish household consumption goods, 1994-2022 median, by ECOICOP-5

Appendix 11: Identified luxuries in other studies

Table 9.11: Identified luxuries in other studies

Luxury goods	Source	Luxury goods	Source
Overly large homes	Wiedmann et al. (2020)	Frequent flying	Barnthäler et al. (2023)
Secondary homes		Air flights	
Oversized vehicles		SUVs	
Meat consumption		Ocean cruises	
First class air travelling		Private jets	
Food away from home	Henry (2014) (US Bureau of Labor Statistics, Consumer Expenditure Surveys, 1984-2012)	Palm oil	Danish Council on Climate Change (2024)
Owned dwellings		Leather	
Household furnishings		Rubber	
Vehicles		Coffee	
Entertainment		Cocoa	
Household operations		Luxury cars	Gough (2020)
Other vehicle expenses		Second property	
		Several long-distance holiday trips a year	
Vehicle fuels	Gough (2019)	Eating out weekly	
Other transport		Expensive hobbies (e.g. pets, horse riding, motorboats)	
Clothing and footwear		A second car	
Furnishings		Animal-based food	
Recreation and culture		Household electrical appliances	Oswald et al. (2023)
Restaurants and hotels		Large homes	
Private health		Package holidays	
Private education		Vehicle purchase	
Mansion	Chancel (2024)	First class air travel	Starr et al. (2023)
Secondary home		Multiple vacation homes	
Luxury vehicles		Private jets	
		Superyachts (>30 metres)	
Private road transport	Creutzig et al. (2022)	Vehicle purchase	Oswald et al. (2020)
Frequent air travel		Package holidays	
Private jet ownership		Vehicle fuel	
Meat-intensive diets		Household appliances	
Entertainment		Transport (air, land, water)	
Package holidays			
Private airplanes	Barros et al. (2021)		
Luxurious yachts (on average 7,000 tons CO2e/year)			
Multiple large dwellings			
Private helicopters			

Note: Not all environmental impact categories are necessarily considered in these studies. Often, it is only carbon footprint.

Appendix 12: Overwriting existing elasticity estimates

Table 9.12: Overwriting existing elasticity estimates based on literature

Consumption item	Best corresponding elasticity item	Current elasticity value	New elasticity value
Meat consumption	"Beef and veal"	-0.03	5.05
	"Pork"	0.03	5.05
	"Lamb and goat"	2.07	5.05
	"Poultry"	1.11	5.05
	"Other meats"	0.00	5.05
	"Edible offal"	-0.15	5.05
Coffee	"Coffee"	0.18	5.05
Cocoa	"Cocoa and powdered chocolate"	0.51	5.05
Household furnishings	"Household furniture"	1.38	5.05
Household electrical appliances	"Other major household appliances"	-1.64	5.05
	"Food processing appliances"		
	"Coffee machines, tea makers, and similar	-5.64	5.05
	appliances"	-1.18	5.05
	"Irons"		
	"Toasters and grills"	-4.54	5.05
	"Other small electrical household	0.00	5.05
	appliances"	1.46	5.05
Frequent air travel	"Domestic flights"	Already > 5.05	Unchanged
	"International flights"	0.93	5.05
Vehicle purchase	"New motor cars"	1.42	5.05
Vehicle fuels	"Diesel"	0.66	5.05
	"Petrol"	1.16	5.05
Package holidays	"Package holidays (domestic)"	-3.25	5.05
	"Package holidays (international)"	2.50	5.05
Restaurants and hotels	"Restaurants, cafés, and dancing establishments"	1.86	5.05
	"Hotels, motels, inns, and similar accommodation services"	3.18	5.05

Appendix 13: Annual average consumption per consumer of a good

Table 9.13: Annual average consumption per consumer of a good

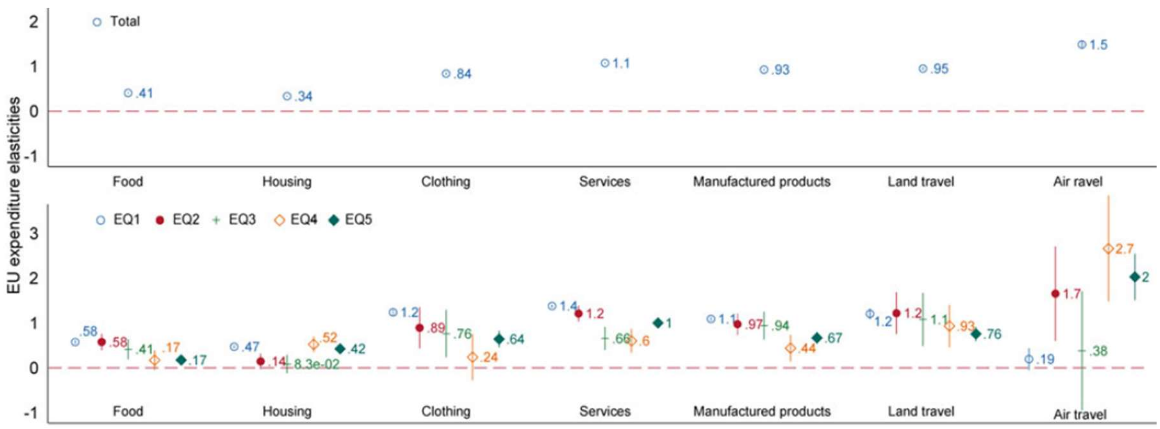
Consumption category	**Unit in consump-tion data**	**Average consumption amount to be used**	**Description**	**Source** (See table 5.8)
Food	kg or litre food supply/ capita/yr		Already stated in average per capita values	FAOSTAT
Passenger car	pkm	7,995 pkm/capita/yr	Total pkm of passenger cars assumed for private purposes is divided by Danish population (+18 years)	Statistics Denmark (PKM1; BEFOLK1)
Hotels	guestnights		Total guestnights divided by Danish population (+18 years).	Statistics Denmark (HOTEL2)
Smartphones	piece		Assuming that 1 smartphone is used by 1 person. Therefore, the environmental impact is impact per annual use of 1 smartphone.	Smartphones sales data in quantities provided by Telenor
Flights	pkm per flight route		It is deemed illustrative to use each scheduled flight route as the unit of annual consumption. Thus, 1 flight from e.g. Copenhagen to Thailand equals “annual consumption of flying from Copenhagen to Thailand per person”.	Provided by Danish Civil Aviation and Railway Authority
Bus, train, metro, ferry, taxi, urban train, metro, scooter 45, bicycle	pkm		Assumed that all Danish people use it. Thus, total annual impact can be divided by total population of Denmark.	Statistics Denmark; Transportvaneundersøgelsen
Heat use, electricity use, water use	Terajoule, kWh, m^3,		Assumed that all Danish people use it. Thus, total annual impact can be divided by entire population of Denmark.	
Household appliances	pieces		1 household appliance of each type per household. On average 2.1 persons per household in Denmark.	Provided by APPLiA DK; Statistics Denmark (BOL106)
Clothes	tons	16 kg/capita/year	Assuming the purchase of 16 kg clothing per person each year.	Danish Energy Agency; Manshoven et al. (2019)
Appliances (EU Consumption Footprint)			Assuming 1 appliance per household and 1 good per household	EU Consumption Footprint[73]

[73] Source: https://eplca.jrc.ec.europa.eu/sustainableConsumption.html

Household goods (EU Consumption Footprint)	piece, kg,		Assumed that all Danish people use it. Thus, total annual impact can be divided by total population of Denmark.	EU Consumption Footprint
Housing (EU Consumption Footprint)	dwelling use[74]		Already stated in 'annual use per person'	EU Consumption Footprint
Food (EU Consumption Footprint)	kg, litre		Total amount of food divided by total population of Denmark	EU Consumption Footprint
Mobility (EU Consumption Footprint)	pkm		Total pkm divided by Danish population (+18 years)	EU Consumption Footprint

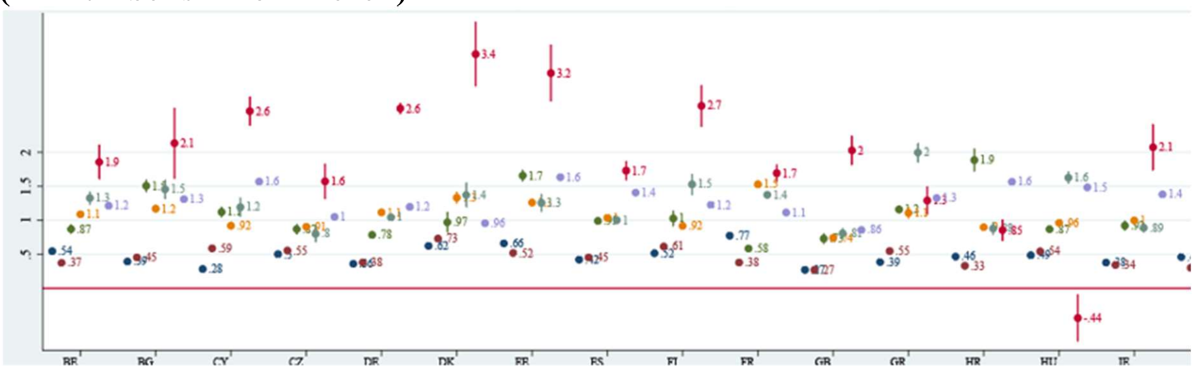
Appendix 14: Expenditure elasticities in other studies

Figure 9.14.1: Ivanova et al. (2020)



Note: EU expenditure elasticities by consumption category (top) and consumption category and expenditure quintile (bottom).

Figure 9.14.2: Expenditure elasticities of consumption categories by EU country (DK number six from the left)



Note: Food (blue), housing (red), clothing (green), manufactured products (yellow), land-based travel (grey), air travel (pink), services (purple)

[74] This is from the EU Consumption Footprint data. It reflects the functional unit "the use of one dwelling by an EU-citizen during one year".

Table 9.14.1: Expenditure elasticities of main consumption categories

consumption category	expenditure elasticity ε	r^2
construction	0.99	0.93
shelter	0.97	0.90
food	0.64	0.92
clothing	0.91	0.89
manufactured products	1.09	0.96
mobility	1.07	0.96
service	1.16	0.98
trade	0.99	0.93
total		

Source: Hertwich et al. (2009)

Table 9.14.2: Expenditure elasticity

Category	Expenditure elasticity	Carbon elasticity
Food	0.37	0.37
Energy	0.14	0.29
Transport	1.60	1.14
Clothing	1.06	1.07
Other	1.02	1.21

Source: Narbel et al. (2014)

Table 9.14.3: Expenditure elasticities (in the second last column)

	All hh	Decile 1	Deciles 2+3	Deciles 4+5	Deciles 6+7	Deciles 8+9	Decile 10	ϵ_{CF}	R^2
Exp. per hh (10^3 NOK)	*511*	*229*	*342*	*410*	*535*	*678*	*949*		
CF per hh (kg CO_2-eq)	22,170	8,557	14,081	16,964	23,448	30,207	43,524	1.14	0.999
01 Food	3,018	1,390	1,862	2,386	3,376	4,145	5,209	0.98	0.986
02 Alcohol & tobacco	333	198	257	265	356	412	551	0.72	0.983
03 Clothing	1,162	529	536	771	1,152	1,730	2,717	1.26	0.932
04 Housing	4,088	1,744	2,713	3,720	4,215	4,879	8,041	1.02	0.976
05 Furniture, etc.	1,280	408	788	983	1,325	1,763	2,666	1.29	0.994
06 Health	632	421	470	581	679	758	915	0.57	0.978
07 Transport	7,864	1,776	5,083	5,569	8,421	11,335	15,923	1.48	0.955
08 Communication	589	457	383	434	640	762	995	0.65	0.791
09 Recreation	1,883	1,091	1,139	1,242	1,957	2,596	3,884	0.97	0.906
10 Education	26	26	13	17	24	37	51	0.70	0.475
11 Restaurants	484	212	316	383	471	676	937	1.05	0.995
12 Misc.	811	305	523	614	832	1,116	1,635	1.17	0.998

Source: Steen-Olsen et al. (2016)

Table 9.14.4: Income elasticities of demand, Denmark

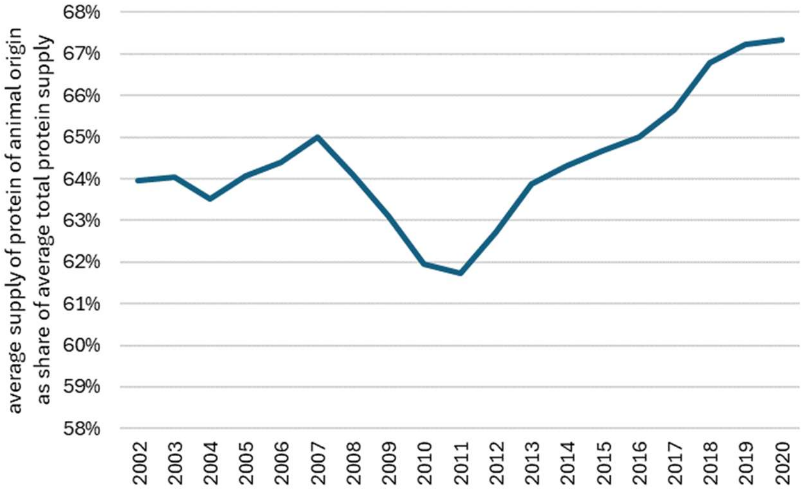
Food	0,97
Alcohol and Tobacco	0,64
Wearables	1,35
Other Housing	0,61
Heating and Electricity	0,65
Household Appliances and Services	1,27
Health	0,63
Vehicle Purchase	2,26
Vehicle Fuel and Maintenance	1,91
Other Transport	0,56
Communication	0,93
Recreational	1,07
Package Holiday	1,00
Education, Finance, Luxury	1,34

Source: Oswald et al. (2023)

Appendix 15: Consumption status of Denmark - Documentation

Food

Figure 9.15.1: Average supply of protein of animal origin (g/cap/day) as share of average total protein supply (g/cap/day) in %



Source: FAOSTAT country profile on Denmark: https://www.fao.org/faostat/en/#country/54

Housing

Average dwelling area per person has been increasing every year from 2010 to 2024. The only place where this has not happened is in the capital area of Copenhagen.

Table 9.15.1: Average dwelling area per capita, m2, 2010, 2024

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Hele landet	51,6	51,7	51,8	52	52,1	52,2	52,2	52,2	52,3	52,5	52,8	53,3	53,6	53,6	53,7
Hovedstadskommuner	45,3	45,1	44,8	44,7	44,5	44,3	44,1	43,9	44	44,1	44,3	44,6	44,9	44,9	44,8
Storbykommuner	48,4	48,4	48,4	48,3	48,3	48,3	48,3	48,2	48,3	48,4	48,7	49,3	49,7	49,8	49,9
Provinsbykommuner	52,6	52,8	52,9	53,2	53,4	53,6	53,6	53,6	53,8	54,1	54,5	55	55,4	55,4	55,6
Oplandskommuner	54,4	54,7	55,1	55,5	55,9	56,1	56,2	56,3	56,5	56,8	57,2	57,6	57,9	57,9	58,2
Landkommuner	57,9	58,3	58,8	59,3	59,8	60,2	60,5	60,7	60,9	61,3	61,7	62,3	62,7	62,7	63,1

Source: Statistics Denmark (LABY46)

Table 9.15.2: Annual growth, number of dwellings, all types, DK, 2016-2024

	2016	2017	2018	2019	2020	2021	2022	2023	2024
- 50 kvm	0,6%	0,1%	0,0%	0,3%	-0,3%	0,0%	0,3%	1,4%	0,4%
50-74 kvm	0,5%	0,3%	0,3%	0,1%	0,2%	0,4%	0,3%	0,5%	0,3%
75-99 kvm	0,4%	0,4%	0,6%	0,5%	0,8%	0,9%	1,2%	0,9%	0,9%
100-124 kvm	0,6%	0,7%	1,0%	0,8%	1,2%	1,4%	1,5%	0,8%	0,9%
125-149 kvm	0,5%	0,5%	0,5%	0,5%	0,5%	0,8%	0,5%	0,1%	0,3%
150-174 kvm	1,0%	0,9%	0,9%	0,9%	1,1%	1,1%	1,2%	1,0%	0,6%
175 kvm og derover	1,7%	1,8%	1,6%	1,5%	1,7%	1,6%	1,9%	1,8%	1,4%

Source: Statistics Denmark (BOL103)

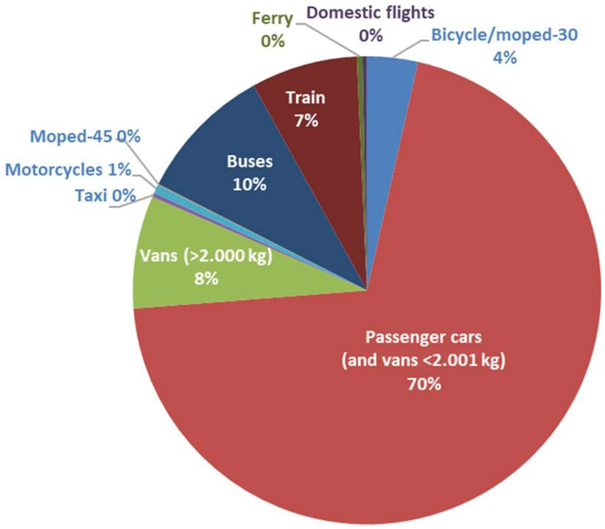
Table 9.15.3: Annual growth, number of single family homes, DK, 2016-2024

	2016	2017	2018	2019	2020	2021	2022	2023	2024
- 50 kvm	0,0%	0,6%	-0,8%	-4,4%	-0,9%	-3,6%	0,2%	-3,4%	-2,3%
50-74 kvm	-2,3%	-2,0%	-2,3%	-2,5%	-2,2%	-2,2%	-2,3%	-2,9%	-2,6%
75-99 kvm	-1,3%	-1,7%	-1,4%	-1,7%	-1,0%	-1,2%	-2,2%	-2,2%	-1,7%
100-124 kvm	-0,6%	-0,7%	-0,7%	-0,9%	-0,6%	-0,7%	-1,1%	-1,1%	-0,9%
125-149 kvm	-0,1%	-0,1%	-0,1%	-0,2%	-0,2%	0,0%	-0,2%	-0,4%	-0,3%
150-174 kvm	0,8%	0,8%	0,7%	0,7%	0,9%	0,9%	1,0%	0,8%	0,5%
175 kvm og derover	1,7%	1,8%	1,6%	1,5%	1,7%	1,6%	1,8%	1,8%	1,4%

Source: Statistics Denmark (BOL103)

Mobility

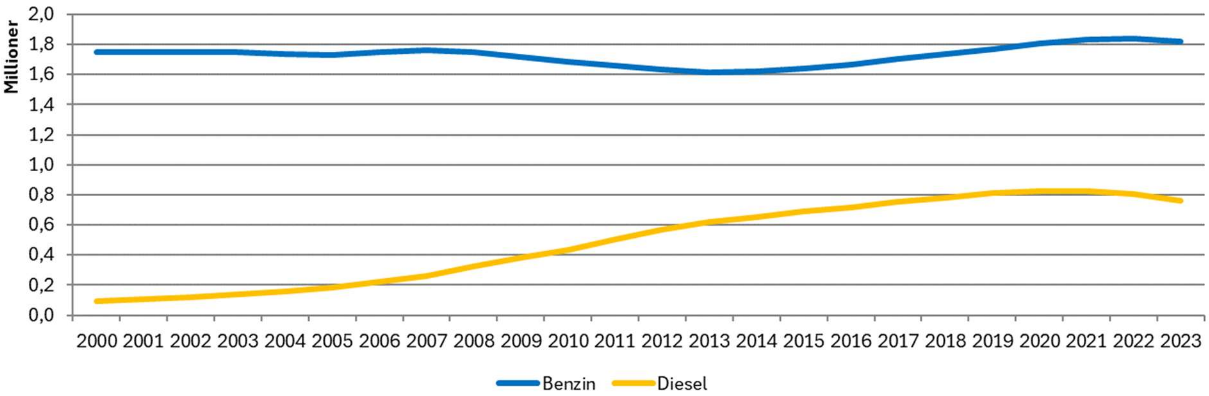
Figure 9.15.2: Annual passenger-kilometres by means of transport, %, Denmark, 2022



Source: https://www.vejdirektoratet.dk/pressemeddelelse/2022/der-er-alt-mange-solobilister-i-danmark

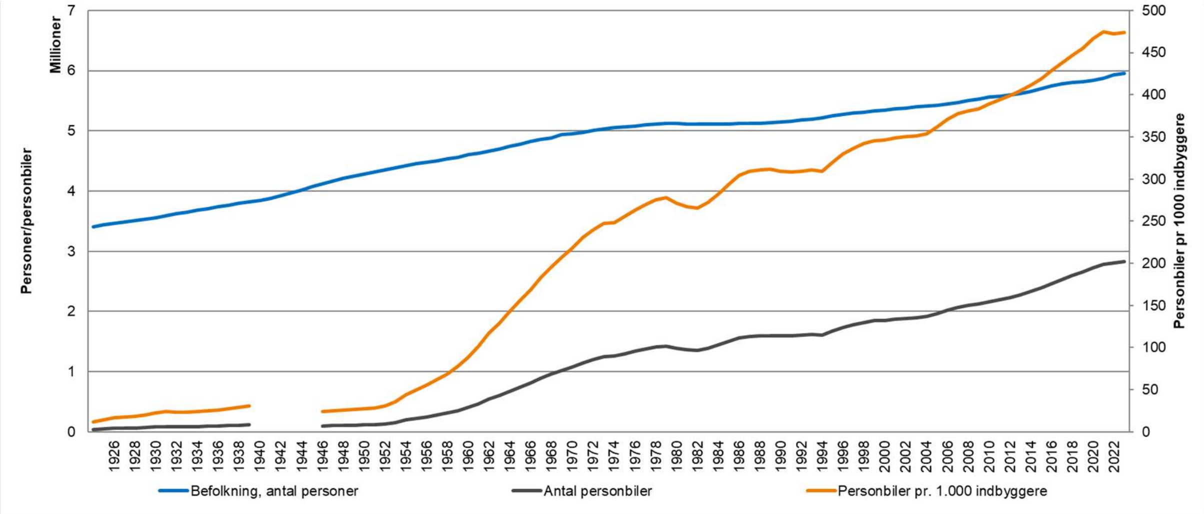
There is an exponential increase in EV car sales in Denmark currently (Trafikstyrelsen, 2023). However, we still need to get rid of all the use of petrol and diesel cars as well. The development in numbers of those have been at best stagnant for years:

Figure 9.15.3: Stock of cars, Denmark, 2000-2023



Furthermore, the number of cars per person has been increasing steadily from 0.35 in 2000 to 0.47 in 2024.

Figure 9.15.4: Number of passenger cars per 1000 citizens in Denmark, 1925-2023



Source: Vejdirektoratet: https://www.vejdirektoratet.dk/side/trafikkens-udvikling-i-tal

Notably, there are around 18% of all households in Denmark that have two cars or more, as seen in this table:

Table 9.15.4: Number of cars per household, Denmark, 2023

	Amount	**% of all households**
Families with 2 cars	481,966	15%
Families with 3 cars	66,673	2.1%
Families with >3 cars	15,483	0.5%

Source: Trafikstyrelsen (KTB4)

Also, when looking at what the distribution of the size of new cars are, it is evident that 55.4% of all new car purchases are SUVs:

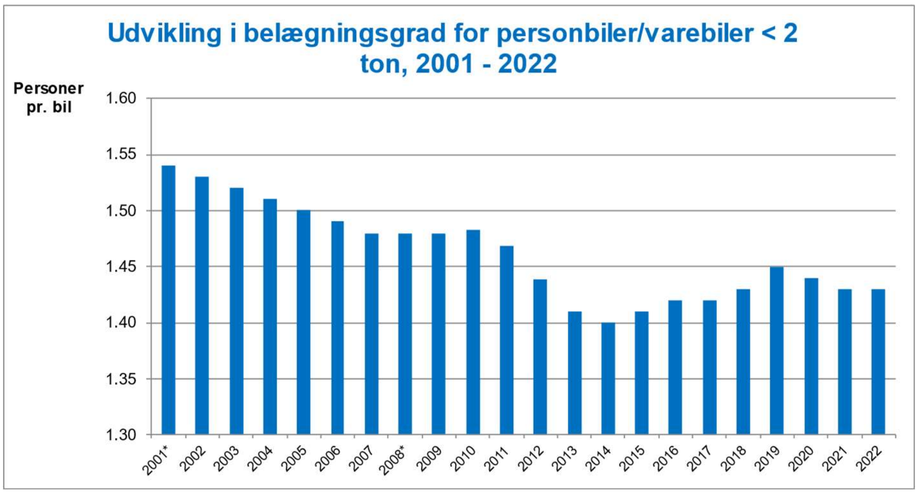
Table 9.15.5: Distribution of car sizes of new car purchases, Denmark, 2023

	Car purchases	**in %**
A: Mikro	5100	3%
B: Lille	27244	16%
C: Mellem	17499	10%
D: Stor	16925	10%
E: Premium	4298	2%
J: SUV	95663	55%
M: MPV	1412	1%
Øvrige	4623	3%

Source: Trafikstyrelsen (KTB8)

In fact, in 2000 the share of SUVs of new car purchases was only 0.6%, and in 2023 it is 55%.

Figure 9.15.5: Load factor of passenger cars, 2001-2022



Source: Vejdirektoratet: https://www.vejdirektoratet.dk/side/trafikkens-udvikling-i-tal

Inequality

Table 9.15.6: Average dwelling size by income quintiles, m2, Denmark, 2010-2022

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Under 250,000 DKK	79	84	83	84	77	78	79	80	82	76	74	69	75
250,000 - 449,999 DKK	100	107	108	109	103	98	94	97	98	98	95	94	92
450,000 - 699,999 DKK	118	119	118	116	117	113	114	111	113	112	112	110	111
700,000 - 999,999 DKK	135	135	136	133	135	136	139	136	134	134	135	136	130
1,000,000 DKK or over	153	151	153	154	154	155	158	146	147	157	160	156	150

Source: Statistics Denmark (FU01)

Table 9.15.7: Number of households in income quintiles, 2022

	2022
Under 250,000 DKK	321.900
250,000 - 449,999 DKK	779.400
450,000 - 699,999 DKK	558.500
700,000 - 999,999 DKK	449.100
1,000,000 DKK or over	663.400

Source: Statistics Denmark (FU01)

Inequality

Table 9.15.8: Average consumption expenditures per person in income interval, relative to lowest income interval (Under 250,000 DKK=100%), 2022

	Under 250.000 DKK	250.000 - 449.999 DKK	450.000 - 699.999 DKK	700.000 - 999.999 DKK	1.000.000 DKK and above
Total household consumption expenditures	100%	129%	383%	1920%	5156%
01.1 Food	100%	112%	343%	1721%	4290%
01.2 Non-alcoholic beverages	100%	116%	313%	1509%	3556%
02.1 Alcoholic beverages	100%	125%	408%	2634%	4370%
02.2 Tobacco	100%	118%	164%	588%	854%
03.1 Clothing	100%	137%	463%	2480%	7074%
03.2 Footwear	100%	89%	294%	1468%	4688%
04.1 Actual rentals for housing	100%	113%	199%	565%	510%
04.2 Imputed rentals for housing	100%	157%	805%	4993%	16276%
04.3 Maintenance and repair of the dwelling	100%	205%	1030%	5121%	13583%
04.4 Water supply & misc. services relating to the dwelling	100%	124%	338%	1840%	4309%
04.5 Electricity, gas and other fuels	100%	135%	346%	1604%	3029%
05.1 Furniture and furnishings, carpets and other floor coverings	100%	233%	489%	2566%	9205%
05.2 Household textiles	100%	177%	632%	6261%	21931%
05.3 Household appliances	100%	80%	299%	2015%	4986%
05.4 Glassware, tableware and household utensils	100%	106%	380%	1701%	6379%
05.5 Tools and equipment for house and garden	100%	127%	412%	2122%	7225%
05.6 Goods and services for routine household maintenance	100%	127%	350%	1798%	5101%
06.1 Medical products, appliances and equipment	100%	179%	377%	1773%	4002%
06.2 Out-patient services	100%	109%	319%	1562%	2733%
07.1 Purchase of vehicles	100%	308%	1360%	10191%	36921%
07.2 Operation of personal transport equipment	100%	134%	579%	3427%	10171%
07.3 Transport services	100%	91%	208%	1144%	3362%
08.1 Postal services	100%	141%	509%	4296%	4235%
08.2 Telephone and telefax equipment	100%	85%	244%	1182%	3201%
08.3 Telephone and telefax services	100%	124%	339%	1580%	3006%
09.1 Audiovisual, photographic & information processing equipmen	100%	193%	383%	1922%	4379%
09.2 Other major durables for recreation and culture	100%	7023%	24417%	212600%	565649%
09.3 Other recreational items and equipment, gardens and pets	100%	121%	493%	2165%	7954%
09.4 Recreational and cultural services	100%	117%	314%	1324%	3632%
09.5 Newspapers, books and stationery	100%	153%	375%	1593%	3288%
09.6 Package holidays	100%	1499%	4379%	16647%	76079%
11.1 Catering services	100%	93%	437%	1567%	5383%
11.2 Accommodation services	100%	187%	748%	4531%	14937%
12.1 Personal care	100%	99%	296%	1247%	3738%
12.3 Personal effects n.e.c.	100%	59%	261%	1142%	4411%
12.4 Social protection	100%	120%	461%	9427%	22418%
12.5 Insurance	100%	140%	512%	2899%	6966%
12.6 Financial services n.e.c.	100%	304%	2504%	7456%	25524%
12.7 Other services n.e.c.	100%	130%	154%	612%	3411%

Source: Statistics Denmark (FU05; INDKP221). Note: Only people at age 14 and above included in data.

Income	Category	2015	2016	2017	2018	2019	2020	2021	2022
Under 250,000 DKK	01.1 Food	17206	17154	17527	18748	17479	16697	17769	17380
	01.2 Non-alcoholic beverages	1897	1956	2317	2304	2124	2073	2315	2246
	02.1 Alcoholic beverages	2252	2264	2701	2725	2413	2318	2162	2238
	02.2 Tobacco	2608	2488	2442	2137	1870	1814	1982	1562
	03.1 Clothing	5060	3576	2839	3014	5375	6912	6493	4090
	03.2 Footwear	1194	866	847	941	947	834	1906	1144
	04.3 Maintenance and repair of the dwelling	849	787	568	646	641	730	511	495
	04.4 Water supply and miscellaneous services relating to the dwelling	4888	4974	5349	5217	4758	4928	4646	4743
	04.5 Electricity, gas and other fuels	16575	15349	18297	19476	18532	15932	18932	13925
	05.1 Furniture and furnishings, carpets and other floor coverings	2482	2391	2303	2724	2420	2847	2588	2187
	05.2 Household textiles	546	429	394	716	804	382	471	233
	05.3 Household appliances	375	539	612	1031	1263	1112	1401	1516
	05.4 Glassware, tableware and household utensils	634	500	617	991	801	956	807	850
	05.5 Tools and equipment for house and garden	465	476	466	408	591	974	760	661
	05.6 Goods and services for routine household maintenance	1633	1328	1323	1333	1271	1242	1356	1512
	06.1 Medical products, appliances and equipment	2328	2492	1493	1888	3041	2688	2583	2399
	07.1 Purchase of vehicles	1768	1722	2529	3888	4154	4169	2618	2004
	07.2 Operation of personal transport equipment	4379	5510	6322	6262	5948	5330	4832	5340
	07.3 Transport services	3457	3063	3370	3736	3406	1857	2514	3661
	08.1 Postal services	67	76	46	41	28	16	7	14
	08.2 Telephone and telefax equipment	942	787	750	1115	997	1226	1414	1344
	08.3 Telephone and telefax services	3910	4886	5073	4645	4596	5048	5220	5024
	09.1 Audio-visual, photographic and information processing equip.	2101	2539	2909	2742	2564	3442	2983	2720
	09.2 Other major durables for recreation and culture	6	-201	-2	213	101	34	693	5
	09.3 Other recreational items and equipment, gardens and pets	2408	2299	2257	3645	3405	2723	2257	2514
	09.4 Recreational and cultural services	6903	6403	6353	5843	5609	4201	4309	4773
	09.5 Newspapers, books and stationery	1810	1419	1120	1032	1321	1217	1092	1059
	09.6 Package holidays	937	1646	2470	1796	992	836	1543	281
	11.1 Catering services	6313	5746	6920	6644	6836	5259	6776	6553
	11.2 Accommodation services	646	1013	811	1375	1407	483	845	1208
	12.1 Personal care	3150	2594	3100	3939	3848	3639	3664	4276
	12.3 Personal effects n.e.c.	777	590	684	886	1356	1245	930	1028
250,000 - 449,999 DKK	**01.1 Food**	24619	25199	25053	25039	24579	24896	22600	20688
	01.2 Non-alcoholic beverages	2472	2306	2513	2804	3051	2779	2654	2773
	02.1 Alcoholic beverages	3045	3548	3160	3347	3096	3149	3291	2979
	02.2 Tobacco	2500	2075	1761	1978	2028	1008	1623	1957
	03.1 Clothing	6121	6124	6556	7535	7996	7078	5442	5955
	03.2 Footwear	1866	1261	1129	1427	1509	1252	1289	1079
	04.3 Maintenance and repair of the dwelling	1765	2111	2952	2357	2121	1853	1353	1082
	04.4 Water supply and miscellaneous services relating to the dwelling	6723	6959	6993	6877	7046	6997	6033	6245
	04.5 Electricity, gas and other fuels	18758	18163	22848	22119	21277	18256	22533	20017
	05.1 Furniture and furnishings, carpets and other floor coverings	5350	3224	3083	2991	2836	4173	4429	5423
	05.2 Household textiles	1439	1343	774	695	517	1093	594	440
	05.3 Household appliances	1298	1975	1941	1352	1210	1311	1627	1296
	05.4 Glassware, tableware and household utensils	1513	956	831	910	1462	1534	1027	958
	05.5 Tools and equipment for house and garden	644	745	723	592	551	742	872	895
	05.6 Goods and services for routine household maintenance	2140	2083	2033	2261	1968	2137	2340	2044
	06.1 Medical products, appliances and equipment	3118	4193	4604	3446	2207	2485	4108	4574
	07.1 Purchase of vehicles	12246	11935	5925	6329	7495	10620	11482	6576
	07.2 Operation of personal transport equipment	12764	12451	11083	10844	10621	11578	8726	7607
	07.3 Transport services	3485	3100	3008	3498	3222	1888	2066	3537
	08.1 Postal services	90	72	50	26	32	57	38	21
	08.2 Telephone and telefax equipment	1050	984	1046	1380	1170	1526	1491	1213
	08.3 Telephone and telefax services	5031	6281	6325	6170	6480	6728	6983	6637
	09.1 Audio-visual, photographic and information processing equip.	2979	3126	2872	2286	2979	4080	3916	5582
	09.2 Other major durables for recreation and culture	285	519	528	211	237	184	87	374
	09.3 Other recreational items and equipment, gardens and pets	4547	4711	4167	4405	6149	6327	4048	3250
	09.4 Recreational and cultural services	9802	7890	7571	7780	7990	6003	5624	5947
	09.5 Newspapers, books and stationery	2187	2392	2426	2034	1916	1840	1731	1729
	09.6 Package holidays	3234	3017	3190	4328	4101	1636	4806	4487
	11.1 Catering services	6902	7306	9164	9141	8338	6553	6050	6518
	11.2 Accommodation services	1688	1507	3515	3101	1335	609	1323	2410
	12.1 Personal care	4858	4701	4624	4655	4878	4728	4374	4512
	12.3 Personal effects n.e.c.	1040	1302	1187	866	846	975	704	648
450,000 - 699,999 DKK	**01.1 Food**	32485	33709	32985	32825	30175	31375	30856	29301
	01.2 Non-alcoholic beverages	3214	3390	3608	3424	3232	3519	3624	3458
	02.1 Alcoholic beverages	4499	4281	4478	4407	4373	4888	5371	4484
	02.2 Tobacco	2656	2912	2563	2150	2458	2313	2037	1260
	03.1 Clothing	8867	9627	9905	8793	8451	9763	9803	9306
	03.2 Footwear	2049	2170	1646	1725	1967	2239	1930	1651
	04.3 Maintenance and repair of the dwelling	4918	4627	4520	3259	2847	2302	2294	2505
	04.4 Water supply and miscellaneous services relating to the dwelling	8663	8455	8982	8691	8921	8374	7756	7872
	04.5 Electricity, gas and other fuels	21872	21296	23460	23437	23412	18827	24642	23645
	05.1 Furniture and furnishings, carpets and other floor coverings	6892	5143	5756	6852	7797	6781	6800	5256
	05.2 Household textiles	1183	1048	924	545	885	989	1188	724
	05.3 Household appliances	1758	2438	2069	1876	2233	2543	1994	2225
	05.4 Glassware, tableware and household utensils	1962	1295	1091	1563	1626	1847	2145	1586
	05.5 Tools and equipment for house and garden	1575	1689	1663	1538	1192	1904	2109	1338
	05.6 Goods and services for routine household maintenance	3230	2814	2614	2780	2500	2500	2723	2603
	06.1 Medical products, appliances and equipment	3816	4008	4015	4204	3722	4833	4751	4448
	07.1 Purchase of vehicles	21350	16181	14236	19129	20777	19319	14695	13399
	07.2 Operation of personal transport equipment	22848	20743	20011	17424	18975	15305	14635	15205
	07.3 Transport services	4989	4936	5370	5243	4204	2958	2910	3748
	08.1 Postal services	108	136	120	66	29	54	35	35
	08.2 Telephone and telefax equipment	1359	1066	1665	2507	1938	2361	2195	1611
	08.3 Telephone and telefax services	6337	7570	7564	7500	7863	7898	8352	8362
	09.1 Audio-visual, photographic and information processing equip.	3424	2507	3240	4275	3877	4667	5493	5117
	09.2 Other major durables for recreation and culture	359	966	-1173	-667	579	430	-26	600
	09.3 Other recreational items and equipment, gardens and pets	6546	6281	6552	6519	6161	6992	7169	6089
	09.4 Recreational and cultural services	11972	10027	9898	10701	10063	7497	7501	7354
	09.5 Newspapers, books and stationery	2655	2524	2251	2267	2022	1967	2131	1953
	09.6 Package holidays	6189	6091	5835	5698	5165	3349	6062	6047
	11.1 Catering services	12073	13149	14970	14528	13551	9318	10186	14078
	11.2 Accommodation services	2846	3772	4393	3215	2993	1855	2712	4438
	12.1 Personal care	6726	6943	7810	7434	6287	6063	6139	6228
	12.3 Personal effects n.e.c.	2024	2400	2247	2797	2182	2432	1574	1319

Table 9.15.9 (1/2): Consumption per average household across income deciles, real DKK

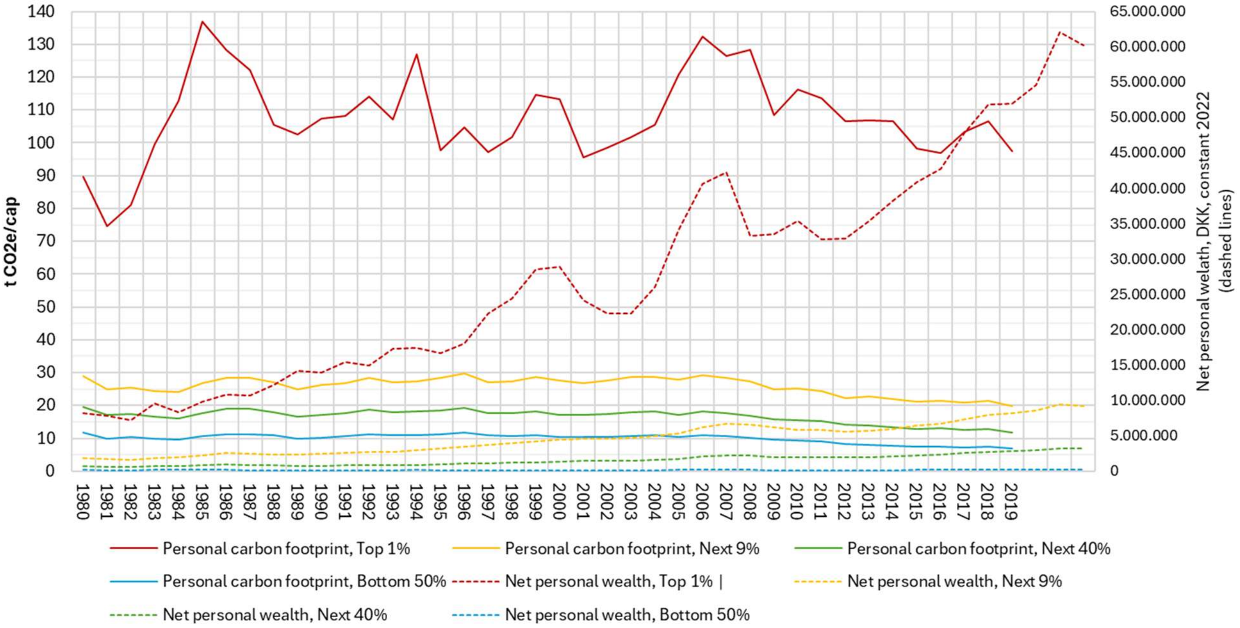
Table 9.15.11 clearly illustrates – only with a few exceptions – that the higher the income level, the higher the consumption level for any consumption category. Some of the largest relative increases in consumption levels across income interval are found in “other major durables for recreation and culture”, “purchase of vehicles”, “package holidays”, “household textiles”, and “maintenance and repair of dwellings”. Notably, these are intuitively consumption categories with energy- and material consumption and environmental impacts embedded to it.

Table 9.15.9 (2/2): Consumption per avg. household across income deciles, real DKK

700,000 - 999,999 DKK	**01.1 Food**	43872	45139	41583	42329	40554	41455	40475	36809
	01.2 Non-alcoholic beverages	3770	3861	4030	3938	4008	4259	4447	4169
	02.1 Alcoholic beverages	5685	5116	5305	5169	5876	6293	6102	7254
	02.2 Tobacco	2992	2392	2088	1927	1997	1565	1262	1131
	03.1 Clothing	11302	11558	10596	10660	11656	11971	10853	12483
	03.2 Footwear	2907	2372	2225	2591	2043	2533	3104	2066
	04.3 Maintenance and repair of the dwelling	6453	7454	5585	4140	3109	3351	3742	3119
	04.4 Water supply and miscellaneous services relating to the dwelling	10365	11342	11616	11460	10901	10632	9377	10740
	04.5 Electricity, gas and other fuels	26512	24920	28049	27037	27604	24037	29006	27476
	05.1 Furniture and furnishings, carpets and other floor coverings	7459	6941	8575	8615	8108	7588	7309	6905
	05.2 Household textiles	1762	1745	1497	1636	1612	2044	1842	1795
	05.3 Household appliances	3295	3142	2693	3422	3592	3554	4293	3758
	05.4 Glassware, tableware and household utensils	3025	2866	1728	1909	2401	2576	2058	1779
	05.5 Tools and equipment for house and garden	2009	2487	2339	2270	1970	2145	2403	1726
	05.6 Goods and services for routine household maintenance	3815	3711	3730	3918	3468	3597	3391	3345
	06.1 Medical products, appliances and equipment	4230	4506	4718	4775	3887	5249	7122	5235
	07.1 Purchase of vehicles	24006	23346	25066	26118	26221	29354	28475	25130
	07.2 Operation of personal transport equipment	27680	28959	27371	27096	27337	25843	22172	22520
	07.3 Transport services	4449	4678	5585	7035	7104	3600	2533	5152
	08.1 Postal services	103	78	77	69	38	46	90	74
	08.2 Telephone and telefax equipment	2114	2116	2019	2725	1971	2936	3211	1954
	08.3 Telephone and telefax services	7682	9213	9439	8929	8723	9392	10010	9770
	09.1 Audio-visual, photographic and information processing equip.	3800	3952	4204	5019	5239	7173	5299	6434
	09.2 Other major durables for recreation and culture	1155	1346	2323	2064	1262	2216	989	1308
	09.3 Other recreational items and equipment, gardens and pets	7683	7398	6669	7472	7523	8993	8158	6696
	09.4 Recreational and cultural services	11387	10517	10319	11402	11054	9294	8379	7776
	09.5 Newspapers, books and stationery	2753	2444	2840	2862	2648	2661	2089	2076
	09.6 Package holidays	6274	7451	9972	9912	6428	6937	14178	5756
	11.1 Catering services	15301	16109	16453	17437	16153	13850	12067	12635
	11.2 Accommodation services	3478	6104	4305	4824	5138	2757	4773	6735
	12.1 Personal care	7513	7588	7968	8863	8011	7108	6947	6561
	12.3 Personal effects n.e.c.	2152	2600	1607	1963	1997	1737	1741	1445
1,000,000 DKK or over	**01.1 Food**	55084	53246	53244	56089	54698	54549	52267	51562
	01.2 Non-alcoholic beverages	5203	4970	5261	5593	5915	5857	5516	5523
	02.1 Alcoholic beverages	7544	7684	7885	8264	8593	8792	7363	6764
	02.2 Tobacco	2266	1681	1448	1387	1498	1570	1265	923
	03.1 Clothing	20300	19741	23299	24371	21521	17512	19174	20011
	03.2 Footwear	5450	4974	4860	4124	3548	3296	3543	3709
	04.3 Maintenance and repair of the dwelling	8412	10069	8133	5804	5539	5504	4624	4650
	04.4 Water supply and miscellaneous services relating to the dwelling	15523	15787	13473	14020	13834	13514	14150	14133
	04.5 Electricity, gas and other fuels	30330	30056	33827	33946	32376	28513	34806	29171
	05.1 Furniture and furnishings, carpets and other floor coverings	13716	12217	13625	13288	12365	13739	15221	13922
	05.2 Household textiles	2675	2088	1741	2004	1998	2868	4544	3534
	05.3 Household appliances	3676	4823	4512	3925	4095	4331	5496	5228
	05.4 Glassware, tableware and household utensils	3444	2664	3514	3390	2745	3094	3475	3750
	05.5 Tools and equipment for house and garden	3363	3543	2623	2517	2850	3385	3387	3303
	05.6 Goods and services for routine household maintenance	5688	6258	6501	6034	6970	6839	5845	5334
	06.1 Medical products, appliances and equipment	3927	3043	3448	5221	5459	6065	6155	6640
	07.1 Purchase of vehicles	30522	31847	40247	41607	36809	49258	45923	51171
	07.2 Operation of personal transport equipment	45330	42829	40871	40697	42069	41792	38847	37562
	07.3 Transport services	8483	9040	9625	10521	10238	5280	4510	8512
	08.1 Postal services	197	192	95	63	52	103	74	41
	08.2 Telephone and telefax equipment	2623	3050	2721	3461	2730	3145	2830	2975
	08.3 Telephone and telefax services	7989	9952	9637	10151	10724	10492	11295	10445
	09.1 Audio-visual, photographic and information processing equip.	5899	6424	6289	6339	7197	10664	10072	8237
	09.2 Other major durables for recreation and culture	2739	4763	4000	6358	8415	5459	3889	1956
	09.3 Other recreational items and equipment, gardens and pets	12163	12362	10917	11591	12279	13707	13278	13830
	09.4 Recreational and cultural services	15609	14520	13726	15002	15613	11742	10142	11989
	09.5 Newspapers, books and stationery	4185	3919	3615	2991	2713	2595	2282	2408
	09.6 Package holidays	11720	11033	12067	10890	11394	11530	23408	14785
	11.1 Catering services	25608	26394	27448	27165	28491	20488	20660	24398
	11.2 Accommodation services	7655	8907	8589	9426	10250	7424	9977	12479
	12.1 Personal care	10112	9884	11732	11431	10181	10554	9725	11055
	12.3 Personal effects n.e.c.	3926	3100	3969	4978	3657	3375	4168	3136

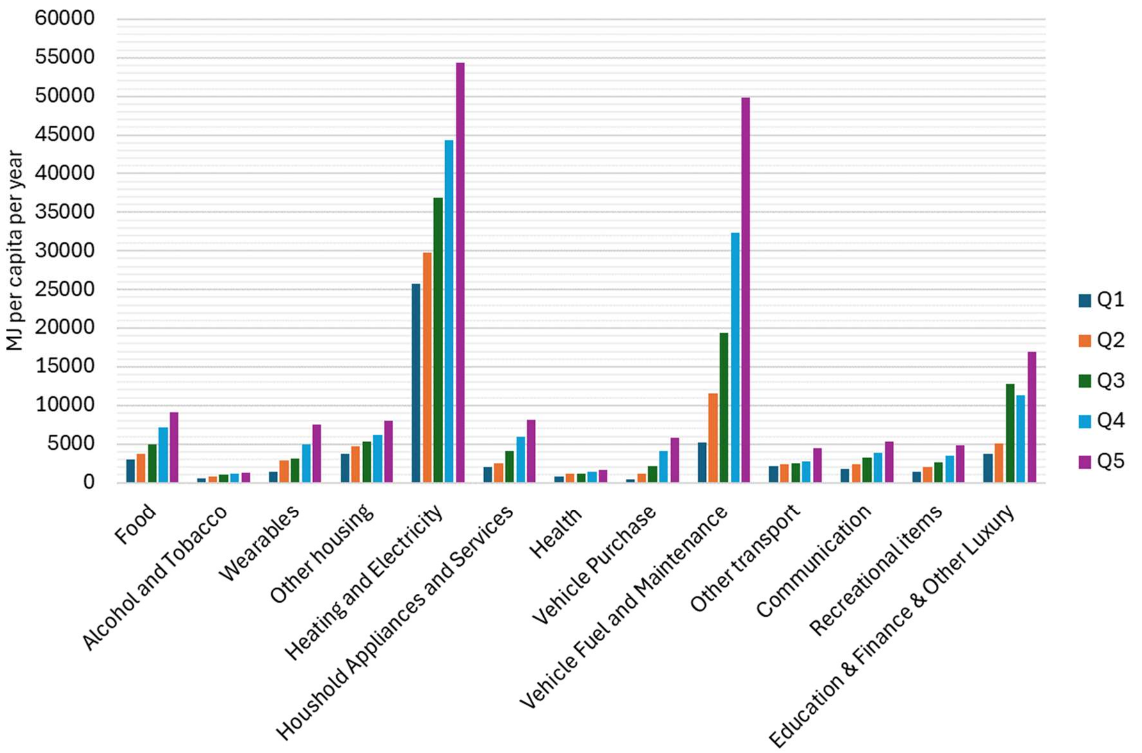
Source: Statistics Denmark (FU05)

Figure 9.15.10: Carbon footprint inequality (solid, left) and Net personal wealth inequality (dashed, right), Denmark, 1980-2019



Source: World Inequality Report 2023. Note: Carbon footprint: Average per capita group emissions, all ages, EURO, ppp, constant 2022. Net personal wealth: Average wealth, adults, equal split, DKK constant 2022.

Table 9.15.11: Energy inequality, Denmark, MJ/cap/year, 2023



Note (Q1: lowest income Q5: highest). Source: Based on Oswald et al. (2020). Scaled up to 2023 population.