Approaching the Limits: The environmental load of Norwegian leisure consumption

JOHN SVERRE RØNNEVIK

Master Thesis in Climate Change Management

Department of Environmental Sciences, Faculty of Engineering and Science

WESTERN NORWAY UNIVERSITY OF APPLIED SCIENCES

Sogndal
June 2019

I confirm that the work is self-prepared and that references/source references to all sources used in the work are provided, cf. Regulation relating to academic studies and examinations at the Western Norway University of Applied Sciences (HVL), § 10.

Western Norway University of Applied Sciences

Approaching the Limits: The environmental load of Norwegian leisure consumption

Master thesis in Climate Change Management

Author:
John Sverre Rønnevik

Author sign.

Thesis submitted:
Spring 2019

Open thesis

Main Supervisor:
Carlo Aall

Co-supervisors:
Hans Jakob Walnum

Keywords:
Sustainable development, leisure, consumption, GHG emissions, ecological footprint, environmental load

Number of pages: 62
+
Appendix: 4

Haugesund, 4.6.2019

This thesis is a part of the master's program in Climate Change Management (Planlegging for klimaendringer) at the Department of Environmental Sciences, Faculty of Engineering and Science at the Western Norway University of Applied Sciences. The author(s) is responsible for the methods used, the results that are presented and the conclusions in the thesis.

Preface

I grew up during the 80s and 90s in Norway. While it might not seem like it today, environmentalism and sustainable development had a big focus at the time. In school I learned about the popular protest movement against hydropower development along the Alta-Kautokeino waterway, the Antarctic hole in the ozone layer, global warming, and the Brundtland Commission, which defined the term sustainable development and recognized the existence of environmental limits to economic growth in industrialised societies. I also learned that communism was failing, while global free trade agreements was beneficial to the Norwegian economy. The latter was reinforced by another source of information with access to cable television, providing a viewport to the world. American television shows painted an appealing picture of the American way of life. The egalitarian way of life in the supposedly classless society of the Eastern Bloc was less certainly less enticing. It must have seemed that way for parents and politicians as well, because lifestyles changed from frugal to borderline prodigal.

I remember this period as a time of action figures, the DJ Kat Show, computer games and skateboarding. It was the time when communism failed, and consumption won. It was also the time when I became an adolescent, and as part of my teenage rebellion joined Nature and Youth and became an environmentalist. As it turned out, I appreciated experiencing untouched nature more than the comforts offered by consumption, and many years later, I still do. When professor Carlo Aall told me about their study on leisure consumption (Hille, Aall, & Klepp, 2007), and suggested that could use my thesis to update the results, I was drawn in. My original plan of writing about how to assess the climate risk and vulnerability to culverts in the Norwegian national road network was shelved.

This thesis is the result of my work. It was more difficult than I envisioned. As it turns out, it encompassed more than finding official statistics, combining them and analysing the results. Neither statistics or data were as available as expected. While I followed established methods, understanding them and knowing which method best applies where necessitates good understanding of how they work. While I am happy with the thesis, what I learned through the process is superior to the written product. To paraphrase Nils Faarlund, somewhere along the way, the path itself became the goal.

While this thesis is my work, it would not be possible without others. I would like to thank my main supervisor professor Carlo Aall for both inspiration and guidance, and for providing me with notes and spreadsheets from their research. These have been a source for both frustration and inspiration, but mainly the latter. I would also like to thank my co-supervisor, Hans Jakob Walnum for providing no-nonsense feedback for my work. Ingun Grimstad Klepp has helped me understand how an industry impact the environment in a myriad of ways by sharing of her extensive knowledge of the textile manufacturing. I am also grateful for the help from Lars Erik Båtveit from Telenor and Øyvind Vevang from NextGenTel. They are childhood friends who shed light on questions on data traffic when official contact channels and statistics came up short. I would also like to thank Guro Henriksen from Statistics Norway, Harald Thune-Larsen from the Insititue of Transport Economics (TØI), Jon Inge Lian from Avinor, Dr. René Benders from the University of Groningen, and Salve Jortveit from Kantar Media. These have all contributed to providing access to or providing data not readily available. Finally, I would like to thank my wife and kids. They are my greatest source of inspiration.

Parts of the data used in the thesis come from “Levekårsundersøkelsen EU-SILC 2012 and 2017”, “Tidsbruksundersøkelsen, 2010”, and “Medie- og kulturbruksundersøkelsen 2012”. These data were collected by Statistics Norway. The data were facilitated and provided in anonymised format by the

Norwegian Centre for Research Data (NSD). Neither Statistics Norway or NSD are responsible for the analysis or interpretations of the data in the thesis. Data have also been obtained from «Den nasjonale reisevaneundersøkelsen 2013/2014). This survey was financed by the Norwegian Ministry of Transport, the Norwegian Public Roads Administration, the Norwegian National Raid Administration, the Norwegian Coastal Administration and Avinor. The data were for the survey were collected by TNS Gallup and provided in anonymised form TØI through NSD. Neither the Norwegian Ministry of Transport, the Norwegian Public Roads Administration, the Norwegian National Raid Administration, the Norwegian Coastal Administration, Avinor, TNS Gallup, TØI or NSD are responsible for the analysis or interpretation of these data in this thesis.

This thesis is dedicated to the late John Hille.

Western Norway
University of
Applied Sciences

Abstract

Through the participation in leisure activities, people consume goods and services that impact the environment. The emission of greenhouse gas emissions constitutes a large part of these impacts, but official inventories do not adequately reflect the actual emissions from consumption. The singular focus on emissions has led to a policy aimed at electrification. While this may lower emissions, it may well be detrimental for other environmental aspects, such as the loss of ecosystem services. This thesis investigates the environmental load of holiday trips by air, IT and internet-based recreation and outdoor recreation in Norway. Energy consumption is used as a proxy for the environmental load, as a low-energy society is also a low-emissions society with low environmental impact. The thesis makes three points: First, the environmental load from the three selected activities is considerable. Second, Norwegian consumers do change behaviour, and the emergence of the internet has caused a shift that appears beneficial to the environmental load. Norwegians' consumption within the three selected categories appear to have reached a limit, where time is the main constraint. Third, transportation and equipment purchases contribute the most to the environmental load. I then conclude with recommendations on policy and research

Sammendrag på norsk

Forbruket av varer og tjenester i fritidsaktiviteter har en miljøpåvirkning. Klimagassutslipp er en viktig del av dette, men det offisielle klimaregnskapet gir et unøyaktig bilde av de faktiske utslippene som følger av forbruket. Det ensidige fokuset på klimagassutslipp i Norge, har ført til en politikk fokusert på elektrifisering. Dette kan gi lavere utslipp, men kan samtidig føre til ytterligere påvirkninger på miljøet for øvrig, blant annet tap av økosystemtjenester. I denne oppgaven ser jeg på miljøpåvirkningen fra feriereiser med fly, IT- og internettbasert underholdning, og friluftsliv i Norge. Jeg bruker energibruk som mål på miljøbelastningen, da et lavenergisamfunn også er et lavenergisamfunn med begrenset miljøbelastning. I oppgaven trekker jeg frem tre hovedpunkt. Først poengterer jeg at energibruken for de tre forbrukskategorien er høy. Dernest poengterer jeg at norske forbrukere ser ut til å endre atferd, og dette er relatert til fremveksten av internett. Samtidig ser belastningen fra de tre kategoriene ut til å ha nådd en grense, hvor tilgjengelig tid er den begrensende faktor. Det tredje punktet er at transport og innkjøp av utstyr er de faktorene som har størst påvirkning. Til slutt avslutter jeg med forslag til politikk og videre forskning.

Western Norway
University of
Applied Sciences

Table of contents

List of tables

Western Norway
University of
Applied Sciences

List of figures

Glossary

ALF	Alpinanleggenes Landsforening. Industry association for ski resorts in Norway.
Carbon leakage	Carbon leakage occurs when there is an increase in carbon dioxide emissions in one country in response to emission reductions in another country. E.g. when you purchase an imported product in Norway, emissions may occur in several other countries because of extraction, production and transport.
Circular economy	In a circular economy, goods have long lifetimes and waste is considered a resource. This is achieved through a combination of product design and services that allow us to reduce, reuse, refurbish, repair and recycle goods (Lacy & Rutqvist, 2015). A simple example is a bicycle produced in a modular way, where components are easily replaced. The bike is repaired when broken and / or upgraded with new components. When the first user no longer needs the bike, it is sold second-hand, and finally, at the end of its life, broken down for parts and recycled
CO_2eq	Carbon dioxide equivalent. The different greenhouse gases have different global warming potential. CO_2eq signifies the amount of CO_2 which would have the same impact as another quantity of a different greenhouse gas. The global warming potential of methane is 25, hence an emission of one tonne of methane equals 25 tonnes carbon dioxide, designated as 25 tCO_2eq.
Ecological footprint	An ecological footprint is a way of accounting the supply and demand side of nature. The demand side describes our consumption of ecological assets, be it timber production, foodstuffs or sequestering carbon dioxide in forests and mires. The supply side is nature's productivity of ecological assets, such as forests and cropland, often referred to as biocapacity. These may be renewable or not. The ecological footprint is the difference between the two (Lin et al., 2018).
Embodied energy / emissions	Embodied energy / emissions is the sum of all energy / emissions required to produce goods or services across its life-cycle.
Friluftsliv	Norwegian term best translated as outdoor recreation first coined by the Norwegian author Henrik Ibsen. The terms are not synonymous, as friluftsliv is part of Norwegian cultural heritage dating back to the Romantic Movement of the 19th century. Friluftsliv is a tradition of identification with nature, emphasising the intrinsic value of free nature and life (Faarlund, Dahle, & Jensen, 2007).
GHG	Greenhouse gases. Gases in the atmosphere that absorb and emit radiant energy. They determine the amount of radiative forcing we can experience, i.e. the amount of incoming radiation that is absorbed in the atmosphere, thus affecting the warming of the planet surface in what is commonly known as the greenhouse effect.
NOK	Norwegian kroner. Currency used in Norway.

PKM	Passenger-kilometre. Unit of measure describing the transport of one passenger by a defined mode of transport over one kilometre.
Skier day	A skier day is a measure of the number of skiers in a resort and is defined as a day of skiing purchased in a ski resort / area. A season pass counts as 20 skier days.

1. Introduction

An oft cited quote by the ancient Chinese philosopher Laozi states that “If you do not change directions, you may end up where you are heading”. Today, we are treading a path towards the future with an ever increasing ecological footprint (Global Footprint Network, 2019). The population is growing, and we produce, consume and pollute increasingly more (Maxton & Randers, 2016; Meadows, Randers, & Meadows, 2004; Randers, 2012). This has paved the way for increasing economic growth and improved living standards across the globe, but not without costs. We consume renewable resources faster than they are replenished. Non-renewable resources are extracted faster than they are substituted with renewable alternatives. Emissions of greenhouse gases (GHG) and other pollutants are too large for our natural sinks, and we create more waste than we are able to reuse or recycle (Maxton & Randers, 2016). In other words, we are in a situation of overshoot, our activities have an environmental load incompatible with a sustainable society (Global Footprint Network, 2019; Meadows et al., 2004). Unless expedient changes are made, we will experience a societal collapse, defined as 50 percent of the wealthy losing most of what they own in a span of less than 20 years (Maxton & Randers, 2016, p. 196).

Norway is little different. Between 1999 and 2012, Norwegian household consumption increased by 26% between 1999 and 2012. According Steen-Olsen, Wood, and Hertwich (2016), the carbon footprint increased similarly. Concomitant, territorial GHG emissions the last decade have been relatively stable, indicating that consumption is driving the emissions (Westskog, Selvig, Aall, Amundsen, & Jensen, 2018). While some categories of consumption are necessary, such as housing and food, those related to leisure activities, such as watching television or going on vacation, are more voluntary.

This makes it interesting to investigate the environmental load of leisure consumption in Norway. Hille et al. (2007) mapped the environmental load of Norwegian leisure consumption in 2007. Their results indicated that what Norwegians’ leisure activities may be less environmentally benign than what we like to think. The study showed that Norwegians’ holiday trips had a large impact, which was hardly surprising. They also showed that outdoor recreation had a large impact. This was more unexpected. In Norway, outdoor recreation is part of a cultural heritage called “friluftsliv”, focused on touching and being touched by nature, and where the intrinsic value of free nature is emphasized (Faarlund et al., 2007). Practicing friluftsliv should have little or no impact on nature at all. In conclusion to their report, Hille et al. (2007) proposed steps towards policies for sustainable leisure time consumption.

There are few indications of a shift in status quo. In 2017 the environmental organization Fremtiden i våre hender (Future in our hands), reported that between 1989 and 2016, the imports of television sets increased by 4.330%, skis by 200% and anoraks by 330% (Thoring, 2017). 5.1 million Norwegians fly equally as much as 50 million citizens within the European Union, and spent 15 billion Norwegian crowns (NOK) on sporting and outdoor goods in 2016, with the average Norwegian spending three times as much on such goods as the EU average (Æra, 2017).

1.1. Research question, limitations and disposition

In this thesis, I will investigate the environmental load of Norwegian’s leisure consumption, based on the following research question: What is the environmental load from Norwegian leisure time consumption of Holiday trips by air, IT (information technology) and internet-based recreation, and outdoor recreation? To answer the main research question, I have three sub questions:

1) Which changes are observed between 2001 and 2012?

2) Which changes are likely between 2012 and 2017, based on available data?
3) Which factors contribute to the environmental load, and how can the load be reduced?

2012 is used as a refence year based on the most recent data from two of the main statistical sources. This will be explained further in the methodology chapter.

My assumption is that the environmental load from the observed activities has increased between 2001 and 2017. This is based on a growth in the Norwegian economy, household income and expenditures in the reporting period (Statistics Norway, 2019k).

1.1.1. Limitations

I have two main limitations in this thesis. I have already mentioned the first. Instead of estimating the environmental load of all leisure activities in Norway, I have only investigated three. The main reason is that covering all activities would likely be outside the scope of a master's thesis. Concomitant, the activities have not been chosen at random. Holiday trips by air have a significant environmental load, as described by Hille et al. (2007). In the case of IT and internet activities, we have seen significant changes since 2001. Computers, game consoles and the internet were certainly common in Norway in 2001, but today these technologies permeate much of our lives. Smartphones, modern tablet computers (e.g. iPad), streaming services (e.g. YouTube and Netflix), and social media services (e.g. Facebook) all entered the stage between 2001 and 2017. Finally, outdoor recreation, which in part requires immersion in nature, has the potential to be low impact to the environment, but was ranked third in energy use for leisure consumption in 2001 (Hille et al., 2007).

The second limitation is the choice of a reference year. As I will explain in the methodology chapter, the research is mainly based on official statistics. While some are published annually, others are published at different frequencies. Three of the main statistics are from 2010, 2012 and 2013/14 respectively, with no later updates. Based on this, I have used 2012 as the reference year. For 2017, I have made estimations based on available data where possible, and assumptions based where data was insufficient for calculations. This is described for each activity in the Results and discussion chapter.

1.1.2. Disposition – a short guide to the thesis

This thesis follows a traditional structure, and each chapter begins with a short introduction describing its structure and content. The chapters and subchapters are arranged in a progressive order, where each part serves as a building block for the next. To facilitate this, the results and discussion of these are presented in the same chapter. This enables an easier reading experience but weakens the boundaries between the chapters. The methodology chapter contains some theory on different methods, while the subchapters for each leisure category describes the specific approach used to estimate the different components in that category.

2. Theory

The focus on climate change and sustainability in media, research, international policy discussion and public discourse has turned related terms and mechanisms into household names. Whether they are climate sceptics or environmentalists, most people have a decent understanding of the concepts of climate change. However, the interplay between consumption, energy use and environmental loads is complex. Due to this, I will use this chapter to describe some key concepts on how emissions are calculated, often referred to as emission inventories, the expediency involved in reducing emissions, the relation between consumption and environmental impact, and finally why energy use is a better proxy for estimating environmental impact than GHG emissions.

2.1. Quantifying greenhouse gas emissions and energy use

GHG emissions in this thesis are given in carbon dioxide equivalents, CO_2eq. This metric is based on the different global warming potential of the different greenhouse gases. Hence, using CO_2eq makes it possible to present emissions as a single number, even if the actual emissions include other gases than carbon dioxide, such as methane, nitrous oxide and chlorofluorocarbons. Energy use is presented in joules, following the International System of Units. In everyday situations and appliances kilowatt hours (kWh) is more common, as is the case for many statistical sources. One kilowatt hour equals 3.6 megajoules. Table 1 provides a short overview on different quantities of emissions or energy use for some goods and services relevant to this thesis. These are just a few examples provided to give the reader a frame of reference. The transport examples were calculated using Vestlandsforsking (2016). Energy use for textile examples were calculated based on data from the United States Environmental Protection Agency (2018). Energy and emission data for internet were calculated using data from Malmodin and Lundén (2018). Other sources are referred to in the footnotes.

Table 1: Examples on quantities of emissions and energy use.

	GHG emissions (CO_2eq)	**Energy use**
Individual	Kilo (kg) and ton (t)	Megajoule (MJ)
National	Megaton (Mt)	Petajoule (PJ)
Global	Gigaton (Gt)	Exajoule (EJ)
Example: Travelling from Oslo to Bergen		
Train (electric)	20.5 kg	499 MJ
Bus (diesel)	30.5 kg	420 MJ
Car (gasoline)	50.3 kg	709 MJ
Airplane	67.3 kg	1219 MJ
Example: Textiles (cradle-to-grave, five-year use phase)		
Arc'teryx Alpha SV shell jacket[1]	27.91 kg	143 MJ
Levi's 501 jeans[2]	33.4 kg	167 MJ

[1] LCA data from Drummond Lawson, Arc'teryx Sustainability Director (e-mail, 12 December 2018).
[2] Data Levi Strauss' LCA (https://levistrauss.com/wp-content/uploads/2015/03/Full-LCA-Results-Deck-FINAL.pdf).

	GHG emissions (CO_2eq)	Energy use
Example: Internet		
One hour of Netflix (HD)[3]	2.4 kg	9.5 MJ
Google searches per second / year[4]	23.0 kg / 0.7 Gt	91.0 MJ / 2.9 PJ

2.2. Greenhouse gas emissions and consumption in Norway

Each year, Norway reports two sets of numbers for anthropogenic, i.e. man-made, GHG emissions, often referred to as emission inventories. The first emission inventory follows the Kyoto Protocol. It comprises all emissions occurring within Norwegian territory, i.e. territorial emissions. The second statistic is required by the European Union (EU) and is used for the union's environmental accounts. These numbers include all emissions resulting from Norwegian financial activity, regardless of where they occur (Høie, Kolshus, & Køber, 2015).

The numbers according to the Kyoto Protocol are reported to the United Nations. These are the numbers you will find in official statistics and reports, and they are used to benchmark how well Norway is performing in cutting emissions. In Norway, this inventory is calculated using a model called "the Cube". The basic equation for the model is simple. Emissions are equal to the activity level multiplied by an emission factor. For each sector, energy use is allocated to technical sources, with different emissions factors, which is described along four axes, or as a cube: fuels, industries, sources and pollutants. The model also accepts data from more detailed supplementary models for several emission sources, such as road and air traffic (Sandmo, 2016). Using reported emission numbers or activity levels as input, "the Cube" is used to calculate the annual emissions for the different sectors in the Norwegian economy. The model has a bottom-up perspective, and accounts for both production and consumption. However, it does not account for carbon leakages, e.g. emissions due to the import of consumer goods. It does account for domestic travel by sea and air, but not to and from destinations abroad. Member countries of the European Environment Agency, which includes Norway, also contribute to the European Union emission inventory. This inventory is slightly different and includes emissions due to each reporting countries' financial activity, regardless of where it occurs. In simplified terms, this inventory includes emissions from Norwegian-owned businesses that operate abroad, while emissions from foreign countries operating in Norway is excluded (Høie et al., 2015). In theory, this inventory includes both international shipping and air traffic, but only if the vessels or aircraft is owned by Norwegian entities. In the case of aircraft servicing international routes, this is rarely the case.

As a contrast to official inventories, researchers have published studies with emissions calculated using multiregional input-output analysis (MRIO), which I will explain further in the methodology chapter. This is a consumption-based approach, where emissions are attributed to the consumer. In 2001, per capita emissions were 9.28 tCO_2eq (Statistics Norway, 2019j). Hertwich and Peters (2009) found per capita emissions to be 14.9 tCO_2eq, using MRIO-based on data from the Global Trade Analysis Project (GTAP). For the previous year, Peters and Hertwich (2006) estimated that Norway had a carbon leakage of 30

[3] One hour of streaming from Netflix in HD quality uses 3 gigabyte of data per device (https://help.netflix.com/nb/node/87).
[4] Google has a page size of 0.4 megabytes (tested with Pingdom, https://tools.pingdom.com/). Google processed 71,780 searches per second in 2018 (https://seotribunal.com/blog/how-many-google-searches-per-day/).

percent. Using more recent data, emissions appear to have slight reduction int the last decade based on the official accounts, whereas data based on the Eora MRIO (Lenzen, Kanemoto, Moran, & Geschke, 2012, 2013) indicate an increase, as shown in Figure 1. For 2015, the difference is 31.6 megatonnes, in other words 73 percent of Norway's reported emissions. This suggests that Norway reduces national emissions by outsourcing them abroad.

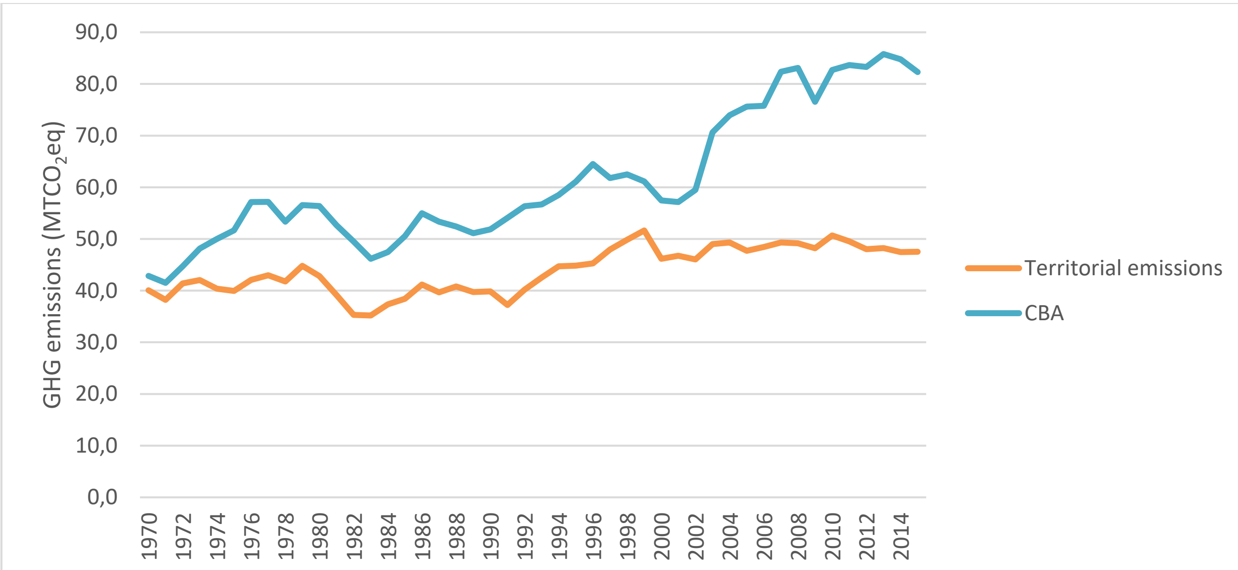

Figure 1: Production based (PBA) and consumption based accounting (CBA) of Norwegian emissions of GHG (KGM & Associates, 2018).

In the case of Norway, consumption-based inventories will inevitably show higher emissions than official statistics, as for all other rich, developed countries that import goods. In theory, this allows rich countries to decouple emissions from consumption. It has been argued that since per capita emissions are used to consider possibilities for reductions, an individual responsibility is implied. If this is to be effective, a consumption-based inventories are required (Hille & Aall, 2010). In the case of Norwegian leisure consumption, this is significant. Norwegians travel extensively, and we import large amounts of consumer electronics and gear for outdoor recreation (Thoring, 2017; Æra, 2017).

2.2.1. The Climate Act and Emission Reductions

Carbon dioxide is a greenhouse gas with a long atmospheric lifetime (IPCC, 2018a; Myhre et al., 2013). According to Archer et al. (2009), CO_2 from the burning of fossil fuels may have a substantial impact on climate for millennia. This means that CO_2 emitted in the dawn of the industrial revolution still remain in the atmosphere, and what is emitted today will remain for centuries unless they are abated by carbon capture and storage (IPCC, 2018a). In other words, emissions of CO_2 and other long-lived greenhouse gases accumulate in the atmosphere. This limits the amount of CO_2 we can emit into the atmosphere, i.e. we are on a carbon budget.

The Paris Agreement aims to limit global warming to well below 2°C and to pursue limits to 1.5°C compared to pre-industrial levels. To limit warming to 1.5°C with 66% probability, the carbon budget leaves 420 $GtCO_2$ of future emissions (IPCC, 2018b). This corresponds to ten years of current emissions (Le Quéré et al., 2018). Based on the Paris Agreement, each signatory country, has pledged to cut emissions through National Determined Contributions (NDCs). In Norway, this pledge has been made into law through the Climate Act (klimaloven). The act states that in 2030, Norway should have reduced emissions by 40% compared to 1990-levels, and 80-95% by 2050 (Klimaloven, 2017). Achieving these goals will require comprehensive cuts. Each year of delayed action needs to be compensated with higher reduction rates the following years, as shown in Figure 2.

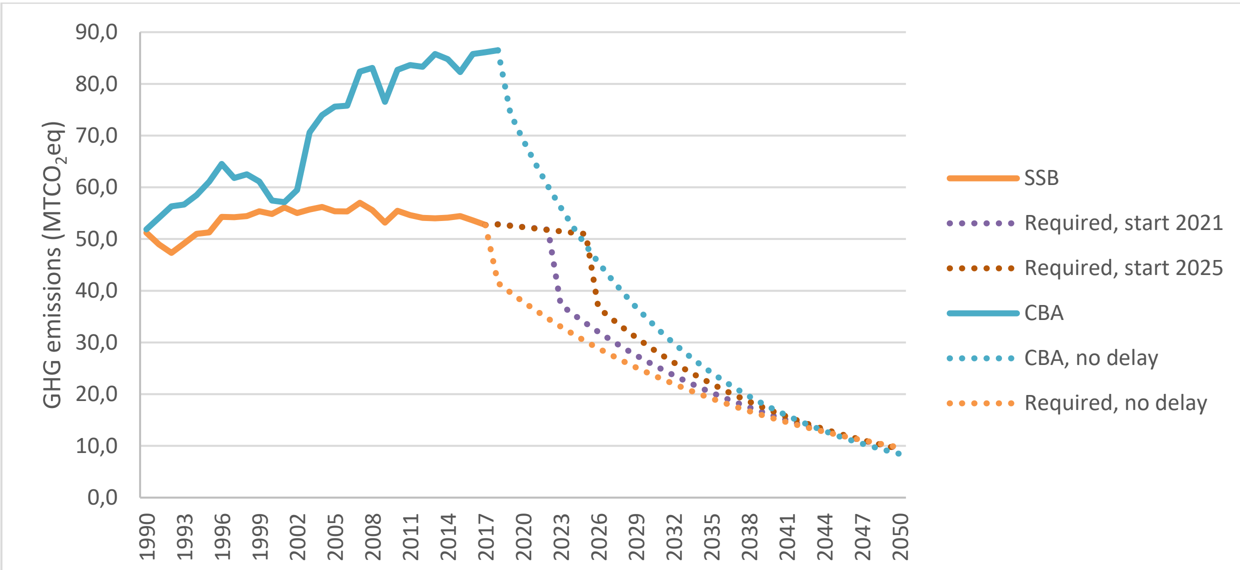

Figure 2: Norwegian emissions of GHG, and reduction trajectories according to the Climate Act (KGM & Associates, 2018; Statistics Norway, 2019j).[5]

While the climate policy debate is fixated on solutions through technology and innovation, it is prudent to question if such avenues of approach will be enough and on time. In 2014, GHG emissions from Norwegian household consumption comprised 60% of total emissions from final consumption (Berglund, 2018). This implies that policy should be directed at consumption change instead (Dubois et al., 2019).

2.3. Leisure consumption

Before we can estimate leisure consumption, we need to separate it from other forms of consumption. I will do this based on the definition used by Hille et al. (2007). Their definition is based on the natural separation between working time and free time. Working time is defined as time spent performing paid labour. This does not include unpaid labour, e.g. time spent studying or household chores such as grocery shopping, food preparation, or cleaning. In other words, leisure time is what is the time left after work time, housework and personal care has been subtracted. Based on this, and we can define leisure activities as activities other than those qualifying as either paid or unpaid labour. Leisure consumption is thus defined as consumption related to these activities.[6]

This is a top-down definition, and it can be argued that consumers may have different definitions. Some may define shopping or coaching kids' soccer as great recreational activities, while others must be forced to partake. Using a bottom-up approach, where the consumers themselves define what leisure activities

[5] Forecast for PBA and years with delayed action calculated using Excel's FORECAST function. Reduction trajectories calculated based on 40% reduction from 1990-levels in 2030 and 85% in 2050 using Excel's GROWTH function.
[6] Hille et al. (2007) also gives a good historical perspective on the development of leisure time, activities and consumption in Norway.

are, is likely to provide a more accurate picture. This would also allow for higher specificity but collecting new primary data on a scale equivalent to that of existing data sources from Statistics Norway would be difficult. Furthermore, aggregating data from such a survey would be hard, due to variations in definition between respondents (Hille et al., 2007).

2.4. Sustainable leisure

Consumer impact on sustainability is well documented in academic studies. Based on a literature review, Aall, Klepp, Engeset, Skuland, and Støa (2011) have found that leisure activities have received little attention in studies on consumption and environment. This is a paradox, as leisure activities has obvious environmental impacts, and because leisure consumption has been increasing. Studies have mainly focused on sustainable tourism, but there have also been studies on the environmental impacts of sports events, fitness culture and the energy use in different categories of leisure consumption. The latter also suggest that the embodied energy-use in leisure consumption is increasing faster than that of other items.

The increase in leisure consumption may be explained through the relationship between income and leisure time. Following the introduction of mass production of commodities in the 1920s, producers needed secure markets in which to tout their goods This could be achieved by increased salaries or reduced working hours. In the end, it was a combination of the two (Cross, 1993). In Norway, the government was concerned as to what labourers would do with the extra hours of free time, suspecting that it could lead to increased alcohol consumption and illicit work. The labour movement, voluntary organizations and commercial actors had a different perspective. Increased leisure time meant an increased market. The 8-hour working day was introduced in 1919, mainly due to the workers' physiological need for rest in order to stay productive (Hille et al., 2007, pp. 29-31). More importantly, paid vacation was introduced by law in 1936, offering workers with weekends and vacations in which they could consume more. This also corresponds to the two diametrically opposed theoretical positions on leisure activities and the environment. The first perspective holds that an increase in leisure time necessitates reduced working hours and income, hence less money to spend and less consumption. Furthermore, increased leisure time provides an opportunity to participate in and be inspired by activities that increase environmental awareness, e.g. outdoor recreation. A study from Sweden suggests this might be the case. According to the study, a 1% decrease in working hours corresponds to a 0.7% - 0.8% decrease in GHG emissions and energy use. Concomitant, it is the reduced income from working less hours that is the main driver, by one order of magnitude (Nässén & Larsson, 2015, pp. 740-741). The other position relates better to Cross' observations. Weekends and vacations are breaks, both from work and sustainable consumption, and individuals treat themselves to more luxury (Aall et al., 2011, p. 456). Aall et al. (2011) have suggested that either of these positions should inform the main strategy for reducing the environmental impact from leisure consumption. While the first position suggests reduced working hours, the second implies more direct measures to reduce consumption.

Based on the findings in Hille et al. (2007), Aall et al. (2011) performed four case studies for leisure consumption in Norway, covering 1) outdoor recreation clothing, 2) cabin use and ownership, 3) leisure boating, and 4) leisure transportation. They identified trends that suggested that both boats and cabins were increasing in size in number, an increase in leisure transportation with a similar increase in the share of private car use, and that Norwegian residents were purchasing more goods for outdoor recreation, a more diversified market for specialized goods, and that these goods were increasingly produced with environmentally problematic materials. In summary, a general increase in purchasing power, reduced prices on many goods and services for outdoor recreation, and an increase in personal mobility. They have found that Norwegians do not necessarily shy away from environmental attitudes, but they lose out in the sum-effect of other good intentions.

Aall et al. (2011) suggest that everyday consumption has reached a physical limit in Norway, while leisure consumption still has a potential to increase. As this is related to economic growth, both political and economic interests are likely to resist changes towards reduced consumption, unless politicians realize that the idea of continuous economic growth may well be incompatible with sustainable development. This position has been around at least since the publication of *Limits to Growth* (Meadows et al., 2004), was mentioned by the Brundtland Commission (Brundtland & Dahl, 1987), and explicitly stated in the last assessment report from The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019). To achieve a change, Aall et al. (2011) proposes that both consumers and producers must be involved, as they mutually dependent on each other, to identify a path where leisure becomes part of the solution through a combination of technological innovation and shift in consumption. This is a combination of ecological modernization and degrowth, two somewhat opposing philosophies on sustainable development. Degrowth can be described as a shrinking of the economy through a downscaling of production and consumption, whereas ecological modernization aims to decouple resource use and production while retaining economic growth. The introduction of a circular economy is such a solution, as this secures revenue for the supply side, while the demand side benefits from reduced prices (Lacy & Rutqvist, 2015).

2.5. Energy use as a proxy for the environmental load

This far, I have presented theory based on GHG emissions. This is natural, as these emissions drive anthropogenic climate change, and thus the focal point for research, media and political discourse. As mentioned, these are the numbers Norway is measured by. As such, GHG emissions may seem an obvious choice as a proxy for estimating environmental loads. However, GHG emissions and ensuing climate change are not the only obstacles on the pathway to sustainability. Human activities impact the environment in myriad ways, and everything you consume has an ecological footprint. To this effect, albeit far from perfect, energy use is a better proxy for environmental loads than GHG emissions.

In this thesis, I have estimated the environmental load with energy use as the proxy. There are several reasons for this. To answer my research question, I had to compare my results with those of Hille et al. (2007). These results are presented in energy use. In addition, according to Kok, Benders, and Moll (2006), energy use is a good proxy for estimating environmental loads, as it is related to three environmental impacts: resource depletion, acid rain, and GHG emissions. They also argue that there is better data availability for energy use. One could argue that this is less relevant in a Norwegian context, as most of our electricity production is from renewable sources. While Norway is a net producer of renewable electric energy (Statistics Norway, 2019l), transportation comprises a large share of Norwegian energy use, with fossil fuels as the main source (The Norwegian Water Resources and Energy Directorate, 2018). Norway is also part of a common electricity market. This allows the export of renewable energy, giving the receiving countries a cleaner energy mix. Concomitant, increasing energy use in Norway may dictate increased imports of electric energy from foreign markets, resulting in a more carbon intensive energy mix in Norway (Energifakta Norge, 2017; The Norwegian Water Resources and Energy Directorate, 2017). Finally, renewable energy production is not without environmental consequences. Hydropower, the main source of electricity production in Norway, is shown to negative impacts on factors such as biological diversity, water temperature, sediment transport and erosion (Bakken, Sundt, & Ruud, 2012).

Norwegian politicians show a keen interest in increasing the production of renewable energy in Norway. This is partially motivated by a potential need for renewable energy production due to electrification of the transport sector, but also by the potential for economic growth. The basic concept is to expand production of renewable energy to become "Europe's green battery". This is possible as hydropower reservoirs can store energy from other renewable energy sources, such as wind power. At the time of writing land-based wind power production appears to be the preferred strategy. This is due to both technical and regulatory factors, such as the lack of ground rent and short depreciation times for wind power facilities (The Norwegian Water Resources and Energy Directorate, 2019a). Concomitant the Norwegian Environment Agency has published nine thematic reports that highlight the environmental consequences of onshore wind power, including loss of habitats and natural areas for outdoor recreation (The Norwegian Water Resources and Energy Directorate, 2019b). This illustrates the inherent danger of a unilateral focus on emission reductions through electrification. Through the actions of reducing one type of environmental impact, namely GHG emissions, the energy demand is amped up, necessitating the development of new power plants. The plants must be constructed somewhere, and through zoning changes, another form of environmental impact may occur, such as the loss of carbon sinks. In addition, the use of heavy equipment, concrete and other materials have both direct and indirect GHG emissions. This can be illustrated as a loop where one environmental impact is exchanged for another (Figure 3).

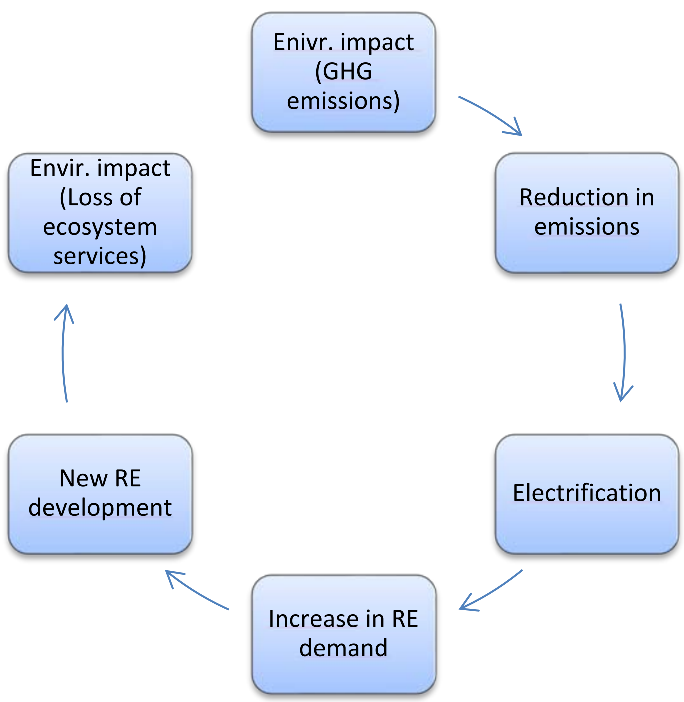

Figure 3: The relationship between renewable energy development and environmental impacts.

From the perspective of ecological accounting, which measures the supply and demand of nature, electrification at the expense of natural areas is unsound. While there is a reduction on the demand side, as a lower amount of carbon needs to be handled by natural sinks, there is a simultaneous, and perhaps irreversible loss, on the supply side. If the area was previously unharvested, e.g. a forest, the loss is more severe, as it also reduces the capacity to absorb emissions (Lin et al., 2018). Naturally, this is impossible to quantify in general terms, as different locations proposed for development have different properties. In Norway, one of the key objections from the popular movement against onshore wind power is the loss of forested areas. A study from Sweden has found that clear felling 23.04 hectares requires 13.4 years of operation to break even when comparing emission savings to lost sequestration, and that there are diminishing returns in CO_2 savings as the deforested area increases (Enevoldsen, 2018). It should be noted that this only addresses the CO_2 balance from deforestation, and not the potential loss of habitats and other ecosystem services from clear-felling a forest. Similarly, renewable energy production, and the electrification of transportation, requires environmentally sensitive materials. Reports suggest that the current rate may be unsustainable. The projected demand for cobalt, lithium and nickel are higher than available reserves. Mining processes require large amounts of energy, resulting in emissions, and include chemical processes that cause pollution. In the case of rare earth minerals waste generation is substantial. In many cases, this occurs without compensation for affected communities. Finally, working conditions are hazardous, and in the Congo there is extensive child labour. This can only be addressed by sustainable sourcing and increased recycling (Dominish, Florin, & Teske, 2019). To keep in balance, three tenets apply: 1) renewable sources can only be harvested as fast as they regenerate, 2) non-renewable resources cannot be extracted faster than they are replaced with renewable alternatives, and 3) pollutants and waste must be emitted slower than natural sinks can handle them (Daly, 1991, p. 256).

2.6. From theory to practice

What is the take-home message from these theories, and how can they be applied in this thesis? First, emissions should be handled from a consumption-based perspective. Local emissions are just part of the problem. Time is limited, expedient action is required, and leisure consumption is a significant contributor to emissions. While electrification may reduce local emissions in the short run, it comes with issues of its own, and may even be unsustainable in the long run. Neither are emissions are the only environmental consequence of consumption, and the theories suggest that a low-energy society is also a low-emission society with low environmental loads. Based on these theories, I will use the following chapters to describe a methodological approach to estimating the energy use from a consumption-based perspective. I will then use these methods to estimate the energy use, and hence the environmental burden of holiday trips by air, IT and internet-based recreation, and outdoor recreation.

3. Methodology

To answer the research question, it is necessary to determine the energy use for the observed activities in 2012 and 2017. Determining the absolute energy use is not the only relevant metric. To determine how changes can be achieved, it is also important to determine the energy intensities by expenditure and time use. The overall approach is explained in 3.1, while I describe the specific methods in 3.2 to 3.4. The main statistical sources and uncertainty is described in 3.5 and 3.6.

3.1. The overall approach

To facilitate comparison with the 2001-results from Hille et al. (2007), I had to follow their approach. This involved some limitations and challenges. As an example, the national travel survey from 2001 had data that were no longer reported on in the 2013/14 version. While this was compensated for using supplementary sources in most cases, there were instances where no data was available, making calculations impossible. However, this is outweighed by the advantage of being able to compare results over an extended period. Figure 4 provides a schematic view of the process.

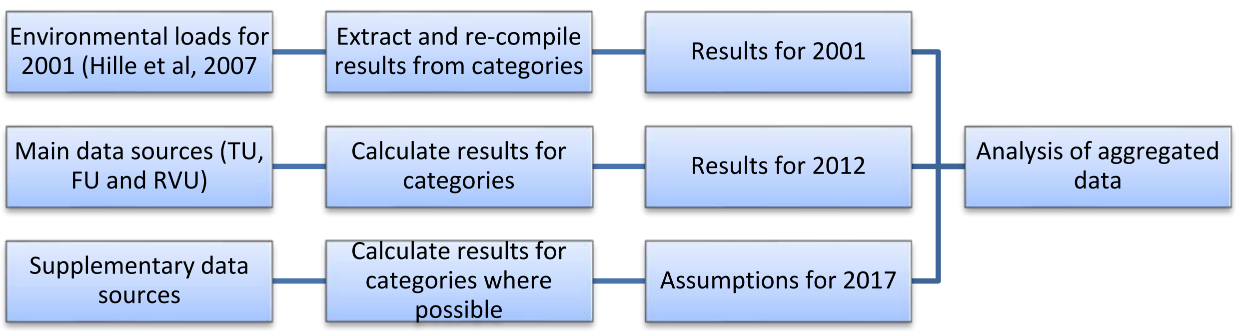

Figure 4: Systematic overview of the steps in the process.

To calculate energy use from the activities, I used a hybrid life cycle assessment (LCA) approach. This approach combines statistical estimation with LCAs and input-output analysis (IOA), which will be explained in further detail below. This approach allows using the best approach based on the statistical data available, and is consistent with Hille et al. (2007) and other studies covering the environmental loads of leisure consumption (Rønnevik, 2019). Explained in a simplified manner, you break a given activity into components, estimate the consumption of each component based on statistical sources, combining this with data from LCAs, IO-tables or statistical sources, and add up the results for each component, as illustrated in Figure 5. The approach differs between activities, depending on available sources and data. I have provided a detail account for the respective activities in the Results chapter.

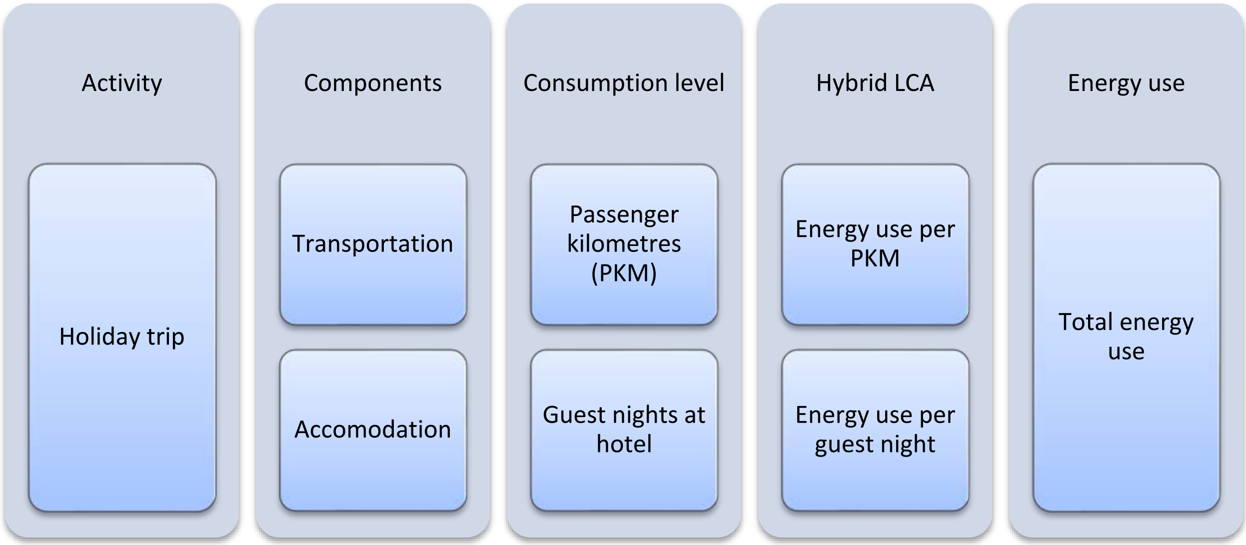

Figure 5: Visualization of the hybrid LCA model, using holiday trips as an example.

The results are given as the sum of all direct and indirect energy use at the primary level. Results from 2001 were obtained from Hille et al. (2007). These were revised as necessary. Physiological energy expenditure, i.e. the use of energy from food to perform activities such as walking, running or cycling, is neglected. This may seem trivial, but human food intake has a significant ecological footprint (Fontana, Atella, & Kammen, 2013; Willett et al., 2019). Nevertheless, humans use energy whether at rest or engaged in a physical activity, and is dependent on several factors such as weight, gender, activity and fitness level. Accounting for this would be problematic, involve a high degree of uncertainty, and be of limited relevance to the research question.

3.2. Life Cycle Assessment (LCA)

A life cycle assessment describes environmental loads for a specific service or product from a cradle-to-grave perspective. The method is based on the collection and analysis of data on how the different processes in the value chain, as illustrated in Figure 6, impact the environment (Scientific Applications International Corporation, 2006). This may be fossil fuel emissions from heavy machinery used to extract minerals, the discharge of chemicals during manufacturing, or the handling of waste when the machinery is worn out and disposed of.

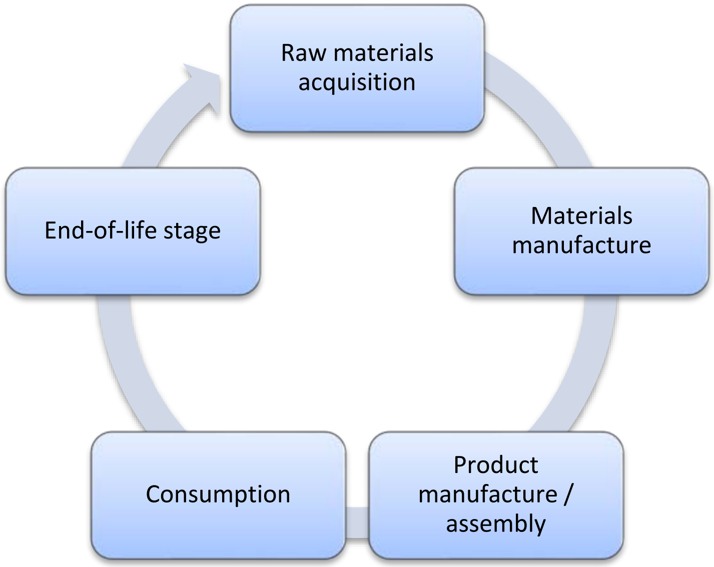

Figure 6: Generic value chain for a product or service in a circular economy.

There are two challenges related to LCAs. The first is that they are specific to a product. An LCA developed for a shell jacket manufactured by Arc'teryx is not directly applicable to jackets from other companies such as Patagonia, Houdini or Bergans. This is in part related to technical factors, such as material composition, place of manufacture, methods for shipping, technical lifetimes, and washing restrictions. The second is related the analysis itself, where the main issue is the boundaries of the analysis. This is decided by the person(s) performing the analysis. While one analysis may decide to include the impacts of making the machinery required to extract resources, another may not. This depends on available resources, such namely time and data. To fully perform a broad and robust LCA for a product, you need LCAs for each material and process involved (Carnegie Mellon University Green Design Institute, 2008). This limits the usability of LCAs at aggregate levels, unless a specific product is responsible for a large share of the impact (Hille et al., 2007), such as the different modes of transport in this thesis.

For buildings and energy conversion between primary and final energy, I have used the data from Ecoinvent (2005) provided in Hille et al. (2007). The main reason for this, is the fact that the data is proprietary, and the university did not have a current license for Ecoinvent. For energy conversion changes this should be insignificant, if applicable at all. For buildings I have commented this in the section on accommodation. This is described in further detail in Appendix A: Source data from Hille et al. (2007).

3.3. Input-Output Analysis (IOA)

Input-output analysis provide a simpler alternative to LCAs. These still have a holistic view, but instead of being based on the processes in a product's value chain, they are based on the monetary and material flows in an economy. Originally, IOA was developed by Leontief (1936) to study financial transactions between different sectors in the economy. This is performed by using IO-tables that describe the flow of materials, represented by their production value, throughout the economy. When you buy a pair of skis at your local sports goods store, the money you spent generate activity throughout the economy. Everyone involved in the providing the skis for you get their share. In turn, they use their shares for other financial transactions, from reinvestments to grocery purchases. IOAs allow us to determine the impact your purchase generated in all sectors of the economy.

Environmentally extended input-output analysis (EEIOA), also developed by Leontief (1970) include information on environmental loads. These are calculated by combining the economic activity in a sector with environmental factors, such as the energy intensity, for the same sector. As an example, the Swedish PRINCE-project provide data on everything from blue water consumption to land use, particle matter emissions, energy use and GHG emissions for 58 product groups, based on IO-tables from EXIOBASE (PRINCE project, 2018). If we know the expenditures for a consumption category, e.g. bicycles, and we are able to allocate it to a corresponding sector, we can use an IO-table estimate the corresponding environmental load (Hille et al., 2007).

There are some weaknesses with IO-tables. They need to describe the specific environmental load we are interested in. If not, you need to know the relevant intensities for that sector. In general, IO-tables have low resolution, i.e. they are normally categorized by industrial sectors instead of specific products and services. There may be large differences in the energy intensities for different products within a sector, e.g. carbon bikes and aluminium bikes are both bikes, but their production require different amounts of energy, giving less accurate results than an LCA would (Hille et al., 2007). Hence IO-tables with low resolution are adequate for results at aggregate levels of consumption, such as groceries, motor vehicles or education services, but are insufficient for more detailed analysis. Unfortunately, there are few IO-tables with high resolution, as these require a great deal of research. Neither is it possible to pick categories from different IO-tables. Each table describes the total flow in an economy, with every measured unit allocated to a specific sector. In other words, when you choose an IO-table, you must stick with it. The method has also received criticism for using national tables, while trade is globalized (Hille et al., 2007). This means that the analysis assumes that imported goods and services are produced with the same technology as domestic production. Multi-region input-output analysis (MRIO) have been developed to account for the globalization of trade (Wiedmann, 2009). These have uncertainties of their own, and often have fewer sectors. Most often, these are used to quantify carbon leakage at the national levels of economies, i.e. sectors such as agriculture, industry, transport et cetera, but lack the explanatory power to describe consumption categories as specific as those used in this thesis.

In this thesis I used the same IO-table used by Hille et al. (2007), albeit adjusted for consumer price changes. This is unfortunate, since this table is in turn based on Dutch data 1996. It is highly likely that there have been changes in the economy, production processes and even materials since that time. That implies that the energy intensities have changed. However, as illustrated in Table 2, I was unable to find a purchase price model where the sectors correlated with the consumption categories in this thesis. Concomitant, in a Finnish study on household consumption by Jalas and Juntunen (2015), an IO-table from 1995 was used. They estimated results from 1987, 1998 and 2009 using the same table, commenting that this gave consistency when comparing results from the different years, whereas using new tables would not. Finally, I only had to use the data from the IO-table to estimate the indirect energy use for equipment in the outdoor recreation category.

Table 2: Reviewed IOA models.

Model	Year	Country	No. of sectors	Price model	Remarks
EIO-LCA	2000	Germany	58	Producer	Producer prices. Poor sector correlation.
EPA	2000	Norway	148	Purchaser	Same model as in Hille et al. (2007), but sector categorization is different.
EIO-LCA	2002	USA	428	Purchaser	Good sector coverage. Test results indicate that model is not suitable for Norway.
EIO-LCA	2007	USA	388	Producer	Producer prices. Model not suitable for conversion to Norway.
AsplanViak	2017	Norway	Unknown	Purchaser	Only covers GHG emissions. Poor sector correlation.
EPA	2018	Sweden	58	Producer	Producer price model, poor sector correlation.

3.4. Statistical estimation

As opposed to LCAs and IOAs, which are holistic in nature, statistical estimation combine data from different statistical sources, normally based on surveys. If we know the average fuel use of a snow groomer, the average service life of snow groomers in Norway, and the number of machines in Norway, we can estimate their annual energy use. These results will always be in final energy and need to be converted to primary energy.

3.5. Statistical sources

I have used three main statistical sources for this thesis. Two are already mentioned, the time-use and consumer expenditure surveys from Statistics Norway. The third is the national travel survey from the Institute of Transport Economics (TØI). The first two were last published for 2010 and 2012 respectively. It is likely that there were few changes in time-use between 2010 and 2012 (Vaage, 2012), and numbers from 2010 were used without adjustment. However, it is likely that there were changes in consumption between 2012-2017, and extrapolating data from the surveys would increase uncertainty. As a result, energy intensities were only calculated for 2012, and this was set as the reference year for this thesis. The most recent publication of the national travel survey covers 2013/14. For the reference year, I have used the numbers “as is” when estimating energy use in transport by other means than aviation. Interpolation was not possible since I did not have the dataset from previous publications, and due to changes in the survey itself. For aviation, I have used supplementary statistics. For 2017, I used supplementary sources when possible, and have provided calculations where possible. In some cases, the lack of data made calculations impossible. This specifically applied to energy use per hour and NOK, but also estimations of energy use for outdoor recreation in 2017.

The advantage of using data from these surveys, is that they have large samples, and data from the reports have been adjusted for statistical errors. For the national travel survey, I also had access to the dataset itself, including a variable for weight adjustment. I analysed data from this dataset using SPSS, making it relatively easy to adjust for statistical errors.

There are downsides as well. While the consumer expenditure survey in principle covers all Norwegian residents, the others do not. Their reference populations are Norwegian residents over the age of 13, and between 9-79 respectively. I have described how I have adjusted for this where applicable. Another problem is that the consumer expenditure survey is categorized according to the Classification of Individual Consumption According to Purpose (COICOP), a reference classification published by the United Nations (United Nations Statistics Division, 2018). While these categories often correlate with data from IO-tables, they differ from the activities covered in the time-use survey. In practice, this limited the applicability of data from IO-tables, as mentioned earlier.

3.6. Uncertainty

There is uncertainty associated with both the statistical sources and methods used in this thesis. First, nearly all the statistical sources are based on sample surveys. A representative sample is drawn from the population and interviewed. The data is then aggregated to cover the entire population. Such surveys are an established and accepted method for providing statistics when counting is impossible due to the population size. As mentioned, these can be adjusted for using statistical methods. Second, even for statistics where counting is possible, there is uncertainty. When Statistics Norway reports that there were 2,376,971 households in Norway in 2017, the number is specific to the last digit. It is unlikely that this number was true throughout the year. Third, both LCAs and IOAs involve uncertainty. While it is possible to provide the exact amount of energy used to produce a specific make and model of a smartphone, it is impossible to achieve the same precision for smartphones as a category. Normally, this handled by studying the robustness of the results using Monte Carlo methods or similar approaches.[7] Fourth, when sources with uncertainties are combined, e.g. multiplying a household expenditure by the number of households, the total uncertainty will increase.

I have tried to reduce uncertainty by using a hybrid LCA, as this allowed me to use the best data in each case. The energy intensities I used are from peer reviewed studies. The statistics are obtained from sources where uncertainty has been controlled for. I did not include ranges of uncertainty in calculations, neither would it be possible, as the uncertainty is not quantified in several of the sources. This may appear as a weakness, but in fact holds little consequence. The justification for this is that the specific results for a specific category at a given time is less relevant than the trend. As I used the same approach in each category, the uncertainties remain consistent and, in the vernacular, cancelled out. Where uncertainties were likely to have impact, this was addressed and described in the results.

[7] Monte Carlo methods is a way of finding the best result, or describing its robustness, by substituting factors where there is uncertainty with a range of values based on probability distribution, i.e. the likely range of the factor. Using these values as input, numerous simulations are run to find the most likely value of the factor.

4. Results and discussion

In this chapter, I present the results in a chronological fashion. Subchapters 4.1 to 4.3 provides the results for each category at the component level, including the approaches used to calculate the results. I present the compiled results in subchapter 4.4.

4.1. Holiday trips with aircraft as mode of transport

As mentioned in the methodology chapter, I have tried to follow the same approach as Hille et al. (2007). They used the 2001 Norwegian National Travel Survey as their main statistical source, supplemented with data from Statistics Norway and Avinor. In this study, our I have mainly relied on air travel surveys. There are three reasons for this.

1. I only observe holiday trips were airplanes are the main mode of transport. Air travel surveys are specific to this mode of transport and published more frequently than national travel surveys. As such, I evaluated these as better sources for our purpose.
2. The national travel surveys have changed, and no longer include all the data necessary to perform the estimations.
3. The approach I use is easier to replicate, and estimations can be updated biannually. With small changes, our approach can be used to cover all modes of travel on an annual basis, albeit with increased uncertainty.

4.1.1. Air travel

To estimate the energy use in air travel, I need to perform separate calculations for vacations domestic and abroad. There are several reasons for this. First, I want to investigate if holidays in Norway have a lower impact than those in foreign countries. Even if I only wanted aggregate numbers, I cannot use the same statistics.

Number of trips

To calculate passenger-kilometres for international travel, I had to estimate the number of trips. For domestic travels, this was unnecessary as the passenger-kilometres were provided in the statistics. However, the numbers were necessary to calculate energy use in accommodation, as described in 4.1.2. For ease of reference, I present the numbers in the same table. I also include an additional set of numbers, based on a different source. The first numbers are based on the passenger traffic reported by Avinor (2013a, 2013b, 2018a, 2018b) and national air travel surveys (Denstadli & Rideng, 2012; Denstadli, Thune-Larsen, & Dybedal, 2014; Thune-Larsen & Farstad, 2018). The second set of numbers are from Statistics Norway. I have included the numbers from Statistics Norway, as this statistic is published annually, and provide data for all modes of transport by purpose. As such, this statistic may provide a simpler approach for estimating the environmental load of all leisure trips.

Table 3: Number of holiday trips in 2012 and 2017 (in thousands), based on reporting by Avinor and Statistics Norway

Source	Destination	Number of round trips, 2012 (1000)	Number of round trips, 2017 (1000)
Avinor	Domestic	1,854	2,212
	Abroad	4,550	4,763

Source	Destination	Number of round trips, 2012 (1000)	Number of round trips, 2017 (1000)
Statistics Norway	Domestic	1,230	1,600
	Abroad	5,010	5,110

As shown in Table 3, there is a significant difference between the numbers. Neither are the deviations consistent between domestic and international trips. I was unable to ascertain why but would like to point out two contributing factors.

1. Statistics Norway interview a representative group of the population consisting of 2,000 Norwegian residents aged 16-79. Respondents are asked if they travel alone, and who they travel with, but not the number of people in the party. Statistics Norway do not indicate a range of uncertainty in their data, but the data are treated for statistical errors. Air travel surveys are based on interviews performed in airports owned by Avinor, combined with data from Avinor. Respondents in this survey are aged 12 years and up. Respondents state the size of the travelling party. Passenger statistics from Avinor, which are used to adjust for skewness, cover all traffic but do not include sociodemographic data. Hence, there are uncertainties regarding the distribution between Norwegian residents and foreigners.
2. When calculating the number of round trips based on passenger statistics and air travel surveys, I used different approaches for domestic and international trips, as shown in Figure 7. I did this to reduce data manipulation. Data manipulation may increase uncertainty in each step, which I want to avoid. Fewer steps also facilitates easier updates in the future.

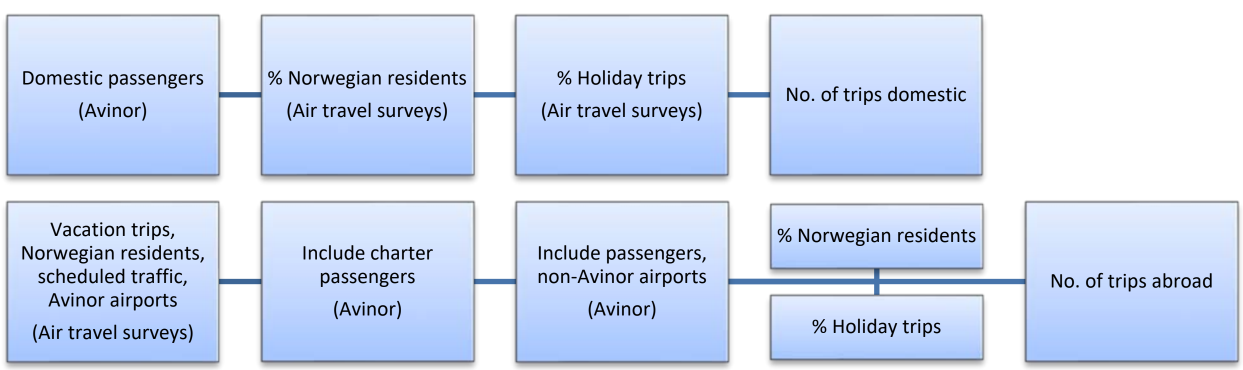

Figure 7: Diagram of trip calculations based on air travel surveys and passenger traffic

I used numbers from Avinor and air travel surveys in our calculations, as I considered these to be more exact, as samples are larger, and the data are adjusted according to actual passenger traffic. Finally, these numbers appeared most consistent with earlier calculations (Hille et al., 2007; Hille, Storm, Aall, & Satagøen, 2008). For future studies focusing on the aviation component in all types of leisure travel, the numbers from Statistics Norway may be a more suitable alternative.

Passenger-kilometres, domestic destinations

For domestic travels, Statistics Norway provide annual numbers for passenger-kilometres (PKM) travelled for all modes of transport in Norway. This covers all passengers, both people living in Norway and foreigners, and all categories of travel, from business trips to weekend stays. To determine the number of holiday trips performed by people living in Norway, I need to combine numbers from Statistics Norway (2018a) with data from air travel surveys performed by the Institute of Transport Economics (Denstadli & Rideng, 2012; Denstadli et al., 2014; Thune-Larsen & Farstad, 2018). The latter surveys are published biannually, and the data presented in the reports may differ from year to year. Our reference year falls is between to reporting periods (2011 and 2013). I have used simple interpolation between the two to find numbers for 2012. Results are shown in Table 4. This gives average flight distances of 459 kilometres in 2012, and 455 kilometres in 2017, which I will use as input when calculating energy use.

Table 4: Passenger-kilometres by airplane in Norway, 2012 and 2017.

Type of travel	PKM (mill. km), 2012	PKM (mill. km.), 2017
Total	5,656	5,812
Foreigners' share	492	779
Norwegian residents' share	5,164	5,033
Holiday / weekend trips	852	1,007

Passenger-kilometres, destinations abroad

For travel abroad, I did not find statistical sources providing passenger-kilometres for travels originating in Norway. This rendered a more complex approach necessary. The first thing I had to establish, was the average trip distance. Prior to 2003, The Norwegian Air Traffic and Airport Management (Luftfartsverket), provided detailed accounts of air travel abroad, making it possible to calculate an average with low degree of uncertainty. In 2001, the average distance was 3,100 kilometres, mainly influenced by a large volume of travel to the Canary Islands and the Eastern Mediterranean (Hille, 2015). Since 2001, similar statistics have not been kept by Avinor. To estimate the average distance of all trips, it was first necessary to estimate the average distances to different parts of the world, as shown in Table 5.

Table 5: Average flight distances, by destination in kilometres (Hille, 2015; Hille et al., 2008).

Country	Distance	Country	Distance
Sweden	450	Italy	2,000
Denmark	500	Holland	850
Finland	850	Belgium	1,250
Iceland	1,750	Czech Republic	1,500

Country	Distance	Country	Distance
United Kingdom	1,200	Rest of Europe	2,000
Spain	2,600	USA / Canada	7,600
France	1,500	Asia	8,500
Germany	1,200	Other continents	10,500

The next step was to combine the average distances from Table 5 with the destination distributions in the air travel surveys. The datasets contain many destinations, 621 cities for 2011, 494 cities for 2013 and 495 cities for 2017 (Denstadli & Rideng, 2012; Denstadli et al., 2014; Thune-Larsen & Farstad, 2018). I was not able to obtain these datasets from Avinor. As a result, I performed our calculations based on the 15 most popular destinations in each of the survey reports. These cover approximately 50 percent of Norwegian residents' holiday trips, but do not reflect the distribution of travel in and outside of Europe. In 2012, approximately 80 percent of Norwegians travelled to destinations in Europe, but this increased to 85 percent in 2017 (Denstadli & Rideng, 2012; Denstadli et al., 2014; Thune-Larsen & Farstad, 2018). I adjusted for this by inflating the number of intercontinental trips according to the actual distribution between continents, as reported by Thune-Larsen and Farstad (2018). This gave an average flight distance of 2,900 kilometres (one-way trip), for both 2012 and 2017. Using a similar approach with 72 popular destinations, Hille calculated an average distance of 2,450 kilometres (Hille, 2015). This distance is for travel for all purposes, e.g. both business and leisure trips, which may give a lower number, as business trips to distant destinations are less frequent than holiday trips to similar locations.

I then combined the number of trips from Table 3 with the average flight distance, with results as presented in Table 6.

Table 6: Passenger kilometres (pkm) generated by Norwegian residents' holiday trips abroad

	2012	2017
Number of flights, one-way	9,100,522	9,525,307
Average flight distance (km)	2,900	2,900
Passenger kilometres (million km)	19,256	21,963

<u>Energy use from flights</u>

To calculate the total energy use, it is necessary to include both direct, e.g. fuel consumption, and indirect, e.g. aircraft production, energy use. For aviation, there are several life cycle assessments that provide such data.

Simonsen has published LCA-data for all modes of transportation in Norway (2010). This assessment is limited to flights within Norway and are based on data prior to 2010. A major factor in energy use in flights are associated with landing and take-off cycles (LTO). When looking at energy use per passenger-kilometre, this is important. The longer the flight, the more kilometres the increased energy during LTO cycles can be distributed across. However, demands for energy efficiency in the aviation industry, either due to commercial issues or regulation, or likely a combination of both, has led to lower energy use per passenger kilometre. Hence, numbers from 2010 may be inaccurate for 2017. Cox, Jemiolo, and Mutel (2018) has published an LCA for air transportation in Switzerland. While Switzerland is a smaller country, with different patterns of air traffic than Norway, the assessment gives energy use per passenger-kilometres for several airplane types, including those used in Norway. Cox also provide data from 1970 until today, including projections for the future, and these data may even be used to update numbers from this study in the future. Based on this, I used the Swiss data for my calculations.

As mentioned Cox et al. (2018), give numbers for different aircraft types across different distances. I decided to use data for long narrow body aircraft (LNB) for both trips both domestic and abroad. LNB aircraft have single aisle configuration and seat roughly 200 passengers, e.g. Boeing 737-800 or Airbus 320, typically used in Norway and Europe. These are larger than the Dash-series aircraft used on the short take-off and landing (STOL) network in Norway, but smaller than aircraft used on intercontinental flights, such as the Boeing 787 Dreamliner. I consider this a good approximation. For domestic flights I used a 400-kilometre range based on the average flight distance. For international flights, I used the 2000-kilometre range, as most of the traffic was within Europe. It should be noted that these approximations give conservative estimates, and the actual energy use likely is higher rather than lower than the results in Table 7.

Table 7: Energy use from Norwegian resident's holiday trips

Destination	Energy use / pkm, 2012 (MJ)	Total energy use, 2012 (TJ)	Energy use / pkm, 2017 (MJ)	Total energy use, 2017 (TJ)
Domestic	3.24	2,761	3.10	3,121
Abroad	1.78	46,977	1.70	46,960
Total		**49,378**		**50,081**

4.1.2. Accommodation

Earlier national travel surveys have provided data on lodgings for vacation travel. In the two latest surveys, from 2009 and 2013/14 respectively, respondents have not been asked about lodgings while on holiday. Concomitant, Statistics Norway offer both annual and monthly data for type of accommodation, but these are categorized by trip purpose. In these statistics there are four categories of accommodation as shown in table Table 8.

Table 8: Guest nights on holiday trips by type of accommodation, 2012.

Type of accommodation	Guest nights abroad (million)	Share abroad (percent), 2012	Guest nights, domestic (million)	Share domestic (percent)
Hotels and similar	31.68	54	3.91	11
Other commercial	3.27	6	10.13	29

Camping / specialized	2,41	4	0.25	1
Private / non-commercial	21.36	36	35.38	60

I am only interested in vacations where airplanes are the main mode of transport. Based on this, I have made two assumptions. The first is that the choice of accommodation is evenly distributed between mode of transport, i.e. that people travelling by plane stay in camping grounds or hotels just as often as those travelling by train. This simplification is likely to give a lower estimate of energy use than what is true. However, the “hotels and similar lodgings” category is widely defined, ranging from hotels to motels, where energy use varies from 183 MJ per night to 36 MJ per night according to Hille et al. (2007). The second assumption is that “private / non-commercial” lodgings has the same energy use as the “other commercial” category. In principle the categories cover the same types of lodgings, such as private lodgings and holiday homes, but that “other commercial” services are paid for, e.g. Airbnb and Novasol, while “private / non-commercial” are used free of charge.

I calculated energy for construction, maintenance and operation for each accommodation category, following the approach used by Hille et al. (2007). For hotels in Norway, I used recent estimations of energy use. For other lodgings, I did not find recent studies covering all accommodation categories. Due to this, I applied the same numbers used by Hille et al. (2007). This increases the uncertainty for other types of lodgings than Norwegian hotels.

Based on the dataset from the Norwegian National Travel survey 2013/14 (TNS Gallup, 2016), the average number of nights spent by Norwegian residents at the destination is 7.7 for domestic destinations and 7.6 for international destinations for vacation travels by airplane. I used these data for 2012, as I lacked data necessary to interpolate. I calculated the number of guest nights for each lodging category by combining the number of round trips (Table 3) with average duration of stay, and distributed the results based on accommodation distribution (Table 8), with results shown in Table 9.

Table 9: Guest nights, Norwegian residents on holiday, 2012.

Type of accommodation	Abroad	Domestic
Hotels and similar	18,657,310	7,703,625
Other commercial	1,925,802	795,166
Camping / specialized	1,419,322	586,040
Private / non-commercial	12,579550	5,194,111

<u>Hotels</u>

Hille et al. (2007) estimated the energy use per guest night for hotels by dividing the total energy use in the hotel sector in 2000 by the total number of guest nights in 2001. This was possible as Statistics Norway had published a report giving the total energy use of the hotel industry. This was based on a statistic showing the energy use of different industries in the service sector. This statistic was last published in 2011. From 2011, similar statistics have been available from Enova. However, these only provide energy use per square meter. As there are no statistics available for the total building mass of hotels in Norway in square meters, I could not follow the same approach as Hille et al. (2007). However, Statistics Norway publish annual numbers of hotel rooms and capacity utilization and Hille (2015) calculated the building mass in 2001 by using a factor of 5.7 square meters per guest night. Assuming a constant ratio between rooms and building mass, we used the same factor, albeit adjusted for capacity utilization, to calculate building mass for 2012 and 2017. Based on this, I calculated energy use per night using Enova's numbers for energy use (2013, 2018). It should be noted that in 2017, Enova estimates that only 1% of the hotels in Norway were low-energy buildings (2018). While Enova provide specific numbers for low-energy buildings, the main statistic includes both "normal" and low-energy buildings, making it difficult to differentiate between the two. This is unproblematic for our calculations, as we are estimating the totals, but we would like to note two things: 1) low-energy buildings in accommodation will reduce the environmental load, and 2) the statistics from Enova indicate that the possible reductions are lower than one might expect (14%). Concomitant, our numbers show that energy use per guest night has gone down. This might reflect energy saving measures implemented to lower operational costs, such as energy efficient lighting systems, improved heating systems, and other measures.

Table 10: Energy use in Norwegian hotels, 2001-2017.

Metric	2001	2012	2017
Building mass (m^2)	2,880,702	3,474,321	4,084,219
Energy use per m^2 (MJ), final energy	1,055	947	979
Energy use per guest night (MJ), final energy	185	161	156
Energy use per guest night (MJ), primary energy	280	244	236

In addition to this, I had to include the energy used during construction. Hille et al. (2007) estimated this to 38 MJ of primary energy per guest night based on numbers from Ecoinvent (2005). While there has been increased focus on energy efficient construction in later years, such changes vary between countries and only apply to new buildings, and Norwegian hotels have an average economic lifetime of 53.2 years (Statistics Norway, 2014). Based on this, I used the same number, accepting that this slightly increases uncertainty. This gives a total primary energy use of 282 MJ per guest night for Norwegian hotels in 2012. For hotels abroad, Hille et al. (2007) used 348 MJ of primary energy per guest night. This is based on a study from New Zealand, assuming 50% electric energy, 25% natural gas and 25% heating oil, including the 38 MJs for construction. I used the same value, based on the same reasoning as for domestic hotels.

Other commercial and private / non-commercial accommodation

The New Zealand study also include final energy use for lodgings such as bed-and-breakfasts (128 MJ / guest night) and motels (36 MJ / guest night). The reduced energy use is related to the lower service level offered. I followed the same approach as Hille et al. (2007), and estimate that other commercial lodgings has half the energy use of hotels, 141 MJ / guest night in Norway, and 174 MJ / guest night in foreign locations. As mentioned earlier, I assumed the same energy use for non-commercial lodgings.

Camping / specialized accommodation

For camp sites, the numbers from New Zealand are used both for domestic and foreign destinations. However, I assumed 100% electric energy use for Norwegian camp sites, but 50% electric and 50% natural gas in camp sites in other countries. Converted to final energy, this gives 43 MJ / guest night in Norway, and 61 MJ / guest night abroad.

Total energy use for accommodation

Results per lodging category and totals are given in Table 11, including a 10% addition as the data are not process wide, i.e. statistical rather than based on an LCA or IO-analysis. As for the energy used for aviation, this is a conservative estimate.

Table 11: Primary energy use for accommodation for holiday trips by airplane, 2012

Accommodation type	Guest nights (1000)	MJ / guest night	Total energy use (TJ)
Domestic			
Hotels and similar	7,704	282	2,172
Other commercial	795	141	112
Camping / specialized	586	43	36
Private / non-commercial	5,194	141	732
Addition, 10%			305
Total domestic			3,358
Abroad			
Hotels and similar	18,657	348	6,493
Other commercial	1,926	174	335
Camping / specialized	1,419	61	87
Private / non-commercial	12,580	174	2,189
Addition, 10%			910
Total abroad			10,014
Total domestic & abroad			**13,372**

4.1.3. Total energy use and energy intensities

Based on my estimations, the total energy use for holiday trips with airplanes as mode of transportation was 63,109 TJ in 2012. Domestic holiday trips constitute 6,119 TJ, while trips abroad account for 56,991 TJ.

I estimated time use based on the average trip duration (TNS Gallup, 2016). To account for nights spent while travelling in longer trips, I added 0.5 days. This gave 8.1 days (194 hours) for trips abroad, and 8.2 days for domestic trips (197 hours). I combined this with the number of trips, resulting in a total of 1,248 million hours, which gave an energy use per hour of 50 MJ per hour. This is a 17% decrease from 2001, indicating increased energy efficiency.

Statistics Norway offer annual statistics for holiday expenses. The problem is that it covers all expenses from flights to guided trips and duty-free purchases. Even if my thesis covered all types of transport, this would cause an allocation problem, as the statistic does not provide a break-down of the expenses. This necessitates using data from the 2012 expenditure survey (Statistics Norway, 2013). Only one consumption category in this survey directly related to holiday trips, namely package holidays. This covers several modes of transport. Based on the COICOP definition, which describes this item as “all-inclusive holidays which include travel fares, food and accommodation” (United Nations Statistics Division, 2018), I assumed that the majority of reported expenses in the category are package holidays to foreign locations. Package holidays may include travel by plane, bus, boats or rail. Based on the dataset for the 2013/14 national travel survey (TNS Gallup, 2016), I estimated that 82% of travelers on package holidays arrive at their destination by airplane, and allocated a similar share of the expenses. This is an approximation, as other modes of transport may be cheaper or more expensive.

The expenditure survey has a separate category for accommodation services. The survey only covers household expenditures, which in turn indicates that these are related to leisure consumption. Utilizing professional accommodation services exclude most activities not related to holidays or weekend trips. Due to data availability, I had to assume that the share of travel by airplane is equal to the share of expenses for accommodation. Based on data from the national travel survey, this is a share of 47% (TNS Gallup, 2016). As described earlier, people travelling by plane spend more guest nights at their destination than the average for all modes of transport, especially at domestic locations, indicating that the estimate is low. Concomitant, based on Table 9 we see that roughly 71% of guest nights occur abroad, where accommodation prices are generally lower than in Norway. This would alleviate the first factor. I did not adjust for these factors and can only state that the estimate of accommodation costs is uncertain.

Air travel fares is a separate item in the expenditure survey. This involves all fares, but as mentioned, the survey only covers household expenditures, and we assume that business trips are paid for by others, mainly the employer. We also know that the majority of leisure trips other than vacation and weekend trips are by other modes of transport than airplane (Hjorthol, Engebretsen, & Uteng, 2014). Based on this, I followed the approach used by Hille et al. (2007), and assume that 75% of these expenses are holiday related.

To calculate total expenses per item, I multiplied the reported expense with the number of households (2.23 million) in 2012, as reported by Statistics Norway (Statistics Norway, 2018b). This was combined with the assumed share related to holiday trips by airplane, as described above. The results are presented in Table 12. Dividing the energy use by expenses, we get an energy use per crown of 0.5 MJ.

This is significantly lower than the 2.5 MJ per crown for all holiday trips reported by Hille et al. (2007) for 2001. For air fares prices went down by approximately five percent between 2001 and 2012, while accommodation had a similar increase. Of course, the latter only accounts for accommodation services in Norway, while air fares cover tickets sold in Norway to destinations across the world. At any rate, this cannot explain the difference. That leaves energy efficiency, and our data suggest that this has happened, especially for air travel.

Table 12: Expenses, holiday and weekend trips by airplane, 2012.

Expenditure item	Expense per household (NOK)	Total expenses (million NOK)	Share, holiday trips by plane (percent)	Expenses, holiday trips by plane (million NOK)
Package holidays	8,387	18,670	82	15,309
Accommodation	1,253	2,789	47	1,311
Air travel fare	5,136	11,834	75	8,875
Total				**25,495**

4.1.4. Summary and evaluation of holiday trips by air

As described in 4.1.2, I was unable to estimate the amount of energy used for lodgings in 2017 at a satisfactory level. It may be argued that the energy used to house you on your holidays has a marginal impact. When you leave your house, you turn of the lights. If you are concerned about heating expenses, you may turn adjust the thermostats as well. While you are away, you will not use energy to cook, wash and tumble-dry. You are also likely to stay in quarters smaller than your home, and if you are a family, share these quarters with others. In other words, depending on how energy efficient your home is, and your resolve in energy saving measures, the net difference may be low or even negative. At any rate, what matters most is where you stay, as there are significant differences in energy use. A five-star hotel uses a lot of energy to cater to your comforts and expectations, from spas and saunas to heated swimming pools. A cheap motel may lack such creature comforts, but still provide adequate billeting.

There is also room for improvement on the supply side. New technologies and materials has made zero-energy and zero-emission buildings possible, and in the European Union and partner countries, all new buildings are required to be nearly zero-energy buildings by 2020 (European Commission, 2016). A part of this, was the Nearly Zero-Energy Hotels (neZEH) project. The neZEH included a pilot were 16 hotels were renovated, achieving significant reductions in energy use. The lessons learned indicate that the hotels require favourable regulations and financial incentives to transform, but also that the customer has part to play (European Commission, 2019). This also applies to domestic vacations. As described in 4.1.2, there low energy hotels are in short supply in Norway. Since accommodation services sell guest nights, they inherently operate under time constraints limiting their ability to generate capital. They can raise prices or increase bed capacity utilization, but this may prove a zero-sum game. To increase bed capacity utilization, prices must be cut, and profits remain the same. Introducing energy reducing measures may be a solution. While capital expenditures may increase, operational expenditures go down. If customers reward the hotels for going “green”, the rewards increase.

The transportation component is more important, as the energy used for flying dwarfs most everything else, corresponding to the findings of other studies (Aamaas & Peters, 2017; Dubois et al., 2019; Hille et al., 2007). Aircraft types have increased fuel efficiency and airliners work to increase fuel efficiency to reduce costs (Cox et al., 2018). In a competitive market, savings may lead to cheaper ticket prices, thus enticing consumers to fly more frequently, in other words a rebound effect. While both emissions and energy use are higher per passenger kilometre than most forms of transport, the real driver is the distance. Concomitant, the results indicate a stabilization in the environmental load between 2012 and 2017. This is likely related to time constraints, which I will explain in detail in 4.4.

There are alternatives to travelling by plane. Except for cruise ships, all other modes of transport are more efficient than airplanes, both regarding energy use and GHG emissions (Vestlandsforsking, 2016). Barring intercontinental travel, these may be actual alternatives for many Norwegians. However, there are still structural challenges. Alternatives to aviation are time consuming, and Norway is a country with large geographic distances. In addition, the Norwegian rail network is limited, and unavailable to many Norwegians. If you are going abroad, there is only one option, a daily departure from Oslo to Gothenburg (Sandberg, 2019a). Air travel is often easier and may be cheaper than the alternatives, and Norwegians prefer air before rail (Sandberg, 2019b). More important than this, is the fact that Norwegians are reluctant to stop flying, even considering the environmental consequences (Dæhlen, 2018). In fact, both survey results and studies indicate that flying is the activity Norwegians are least willing to part with for the sake of the environment. Results from the international HOPE project, a study on household preferences for reducing GHG emissions (Westskog et al., 2018), indicate that few Norwegians are willing to reduce flights on a voluntary basis. Even in a forced scenario, where the same cuts would apply to everyone, reductions appear unpopular (Figure 8). This correlates with recent results from the Norwegian Citizen Panel, a web-based survey of Norwegians' opinions, where respondents ranked reducing holiday trips by plane as more difficult than using public transport, reducing meat consumption, buying less goods, buying more energy efficient goods, buying goods with long life expectancy / reusability, and saving energy (Skjervheim & Høgestøl, 2017).[8]

[8] Survey code: r8km7-a-1-7.

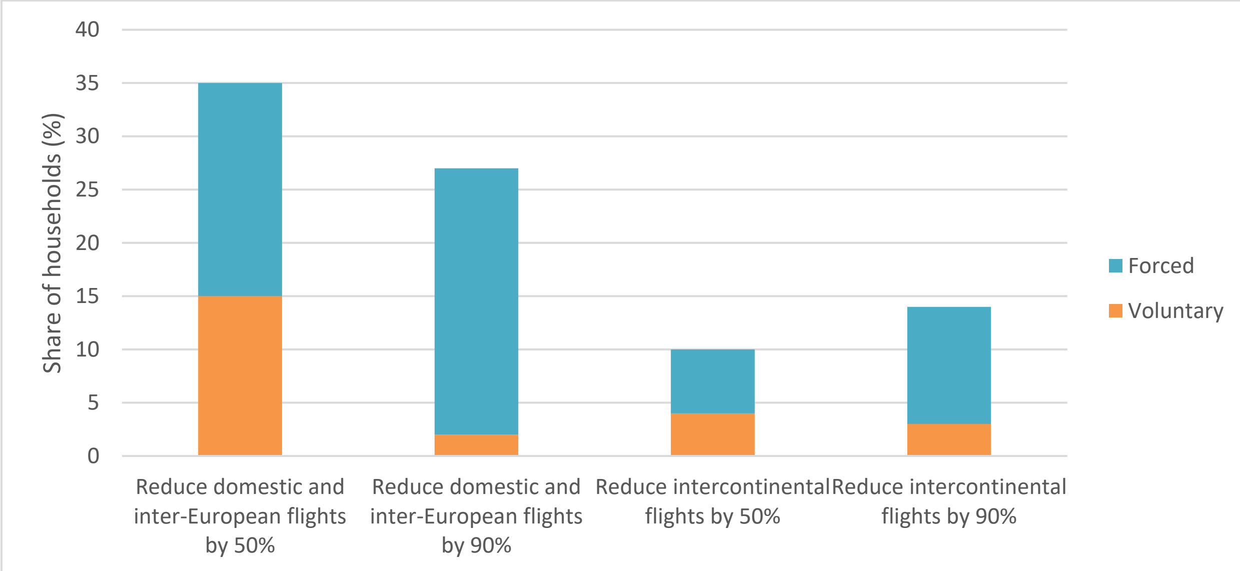

Figure 8: Norwegian households' preference for actions to cut GHG emissions on a voluntary basis or in a forced scenario (Westskog et al., 2018).

As a consequence, electric airplanes has been proposed as a solution to the emission problem by politicians as well as researchers (Dæhlen, 2018). This still externalises environmental loads from production and energy use, and it is not a realistic alternative to long distance flights in the foreseeable future. While electrification may help reduce local emissions in the use face, it will not necessarily abate emissions from other phases in the lifecycle. Furthermore, the energy use will still be substantial, and the development of sufficient renewable energy plants to provide this energy is likely to have other environmental impacts. In any case, based on current projections, switching to electric powertrains is inexpedient. This leaves a change in consumer behaviour as the sole option. This can be achieved by switching to other modes of transport and / or vacations closer to home, as previously suggested by both Hille et al. (2007) and Dubois et al. (2019).

4.2. IT and internet-based leisure activities

While internet had been around for a decade and people played computer games in 2001, there has been a significant change in the ensuing years. Not only is there increased access to digital media and electronic devices (Figure 9), but there has been a significant change in both how much media we consumed, and how we consume it (Figure 10). In 2001, watching television meant following linear programming. Watching movies or listening to audio from the internet meant downloading. Today, changes in information and communication technology (ICT) has changed that. You can watch what you want, when you want it, directly from your internet-enabled television set. You do not even need a television set. Provided you have a subscription, you can watch TV shows from the device of your choice. Similarly, the devices have changed. Cathode-ray tube monitors, disk drives and CD-ROMs are a thing of the past. Smartphones and tablet PCs, which in 2001 did not even exist, are household items today, and Norwegians can stay connected to the internet nearly whenever and wherever they want.

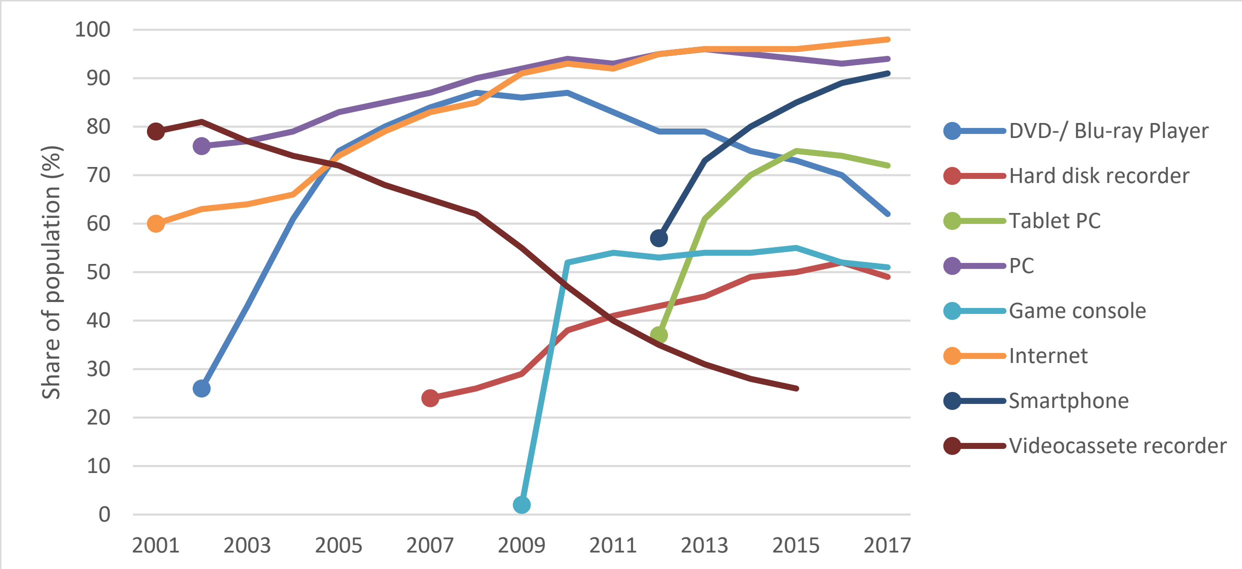

Figure 9: Share of population with access to different media / electronic devices in their homes (Statistics Norway, 2019e).

These changes, also reflected in statistics (Figure 10), makes the distinction between media consumption difficult in statistics. Are you using the internet or watching television when you stream Netflix straight to your television set? When you are listening to a podcast, is that an internet-based activity, are you listening to the radio, or are you consuming audio media? This also creates problems with categorization and allocation. To keep in line with the 2001-results, and to provide an estimation that best reflects reality, I have solved this by 1) limiting the devices in the category to PCs, smartphones, tablets and game consoles (including handheld devices such as the Nintendo 3DS or Nvidia Shield), and 2) using data traffic to calculate energy use for internet-based activities. Regarding 1), regular mobile phones are not included. While such devices may be connected to the internet, usability is limited.

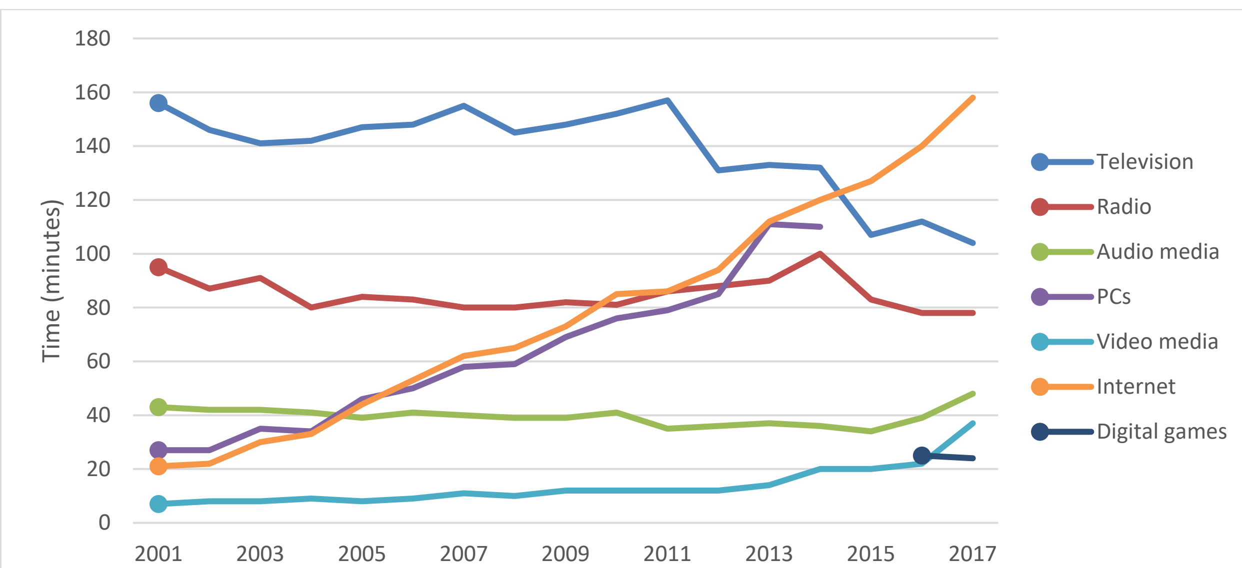

Figure 10: Time used on different media by Norwegians on an average day (Statistics Norway, 2019b)..

4.2.1. Energy use from IT and internet devices

While there are statistics on the number of television sets in Norwegian homes, there are no similar statistics for the devices covered in this category. As mentioned earlier, there are annual statistics on access to devices on a household basis. In addition, there are annual data on units sold and the number of active cell phone subscriptions. The consumer expenditure survey tells us how much households spent on IT equipment in 2012. For 2014 and 2018, reports on Norwegian households' media habits provide device specific expenses for computers, mobile phones and tablets. Combining the reported expenses with data from the IO-table would be an easy way to estimate the energy use from devices. However, using an IO-table based on 23-year-old data for electronic devices would be highly inaccurate. A search on relevant academic literature provided an alternative, a study by Belkhir and Elmeligi (2018) with recent LCA data. This study provides production and use phase emissions, and the lifecycle annual emissions for all devices covered in this thesis, apart from game consoles. Belkhir and Elmeligi (2018) provide estimated minimums and maximums. I used the average, as we do not know the distribution of high-end devices, mid-range and budget devices. The values are in kg CO_2eq, but the study provides the necessary data to convert this to energy. With data on lifecycle annual energy use, it is not necessary to calculate energy use from production and use, we can calculate the annual energy use directly.

To achieve this, it is necessary to know the number of in use. As mentioned, this metric is not covered in the statistical data. Based on this, I had to estimate the number of devices in use in 2012 and 2017 respectively. For computers, I assumed one laptop per single-person household, and 1.5 laptops and 0.5 desktops and LCD-displays for households with more than one person. Laptops were given dominance over desktops, as the latter has been declining in popularity (Belkhir & Elmeligi, 2018). While trends indicate that migration from larger to smaller displays (Malmodin & Lundén, 2018, p. 15), it is expected that external displays for portable devices will be more common, as people connect portable devices to larger screens while at home (Belkhir & Elmeligi, 2018, p. 460). This is hard to estimate as these devices can be connected to virtually every modern display. Since I follow the categorization used by Hille et al. (2007), such displays would belong to the category "audio and video devices", which is not included in this thesis. The numbers are likely on the low side, but the global sale of computers, barring the segment of high-end gaming computers, has been declining since 2011 as smartphones and tablets have ascended towards primacy (Malmodin & Lundén, 2018, pp. 15-16). For game consoles (including handheld devices) and tablets, I multiplied the share of the population with access (Statistics Norway, 2019e) by the number of households for the respective year. For tablets, this correlates with the number of units sold and life expectancy of tablets. Following a spike in 2013/14, sales have stabilized, indicating that people are replacing existing tablets, rather than expanding their inventory. For consoles, I did not find similar statistics. For smartphones, I also used the population share, but multiplied it with the population between 9-79 years of age instead of the number of households. The result correlates well with the number of subscriptions reported by the Norwegian Communications Authority (Norwegian Communications Authority, 2019). The results are shown in Table 13.

Table 13: IT and internet connected devices in Norwegian households, 2012 and 2017.

Device type	Units (1000), 2012	Units (1000), 2017
Desktop computers	673	734
Laptop computers	2,899	2,926

LCD displays	673	734
Game consoles	1,180	1,212
Handheld game consoles	779	547
Tablets	824	1,711
Smartphones	2,400	4,072

To calculate the annual energy use from the devices, I multiplied the number of devices with the lifecycle annual energy use for each device, with results shown in Table 14. Conversely, the estimating the energy use based on consumer expenditures and the IO-table gave 14,180 and 31,565 TJ for 2012 and 2017 respectively, not including annual energy consumption from use.

Table 14: Energy use from IT and internet devices in Norwegian households, 2012 and 2017.

Device type	Energy use, 2012 (TJ)	Energy use, 2017 (TJ)
Desktop computers	884	965
Laptop computers	2,045	2,065
LCD displays	240	262
Game consoles[9]	832	855
Handheld game consoles[10]	254	178
Tablets	173	360
Smartphones	603	856
Total energy use	**5,032**	**5,541**

4.2.2. Internet traffic

To estimate the energy use from internet use, data traffic, i.e. the amount of data transmitted over the networks, is the best metric. The amount of data transferred is directly related to the energy use, from the device in the consumer end, via the service provider in the middle, to the servers hosting the data on the supply side. While the Norwegian Communications Authority provide statistics on data traffic over cellular networks, they do not offer such data for fixed broadband. Neither do Statistics Norway, even

[9] LCA data for laptop computers were used for game consoles, as Belkhir and Elmeligi (2018) do not provide data for game consoles. This assumption is based on a study showing that new game consoles (e.g. Playstation 3 and newer models) had a similar annual energy consumption equal to laptop computers (Webb, Mayers, France, & Koomey, 2013), and that their production include similar types and amounts of material, except for the display screen.

[10] For handheld game consoles, I used the LCAs for smartphones, but with the maximum value as provided by Belkhir and Elmeligi (2018), as handheld consoles perform on a level similar to high-end smartphones, e.g. the Xperia Play.

though they provide numerous statistics on ICT and the digitalization of Norway. The only source for these data is the internet service providers (ISP) themselves. I contacted several large ISPs with mixed results. It appears that ISPs have little interest in tracking the total data traffic on fixed broadband. They are not required to do so by the government, and the information has little value for them. I was also informed that they did not share information on data traffic freely, as this information may have competitive intelligence value, i.e. competing ISPs may gain insights from the data. In the end, Telenor provided me with information on peak traffic in their networks from 2012 until 2018 (L. E. Bråtveit, personal communication, 4 April 2019). Peak traffic, by definition, only reveals the highest transfer of data at a given time. However, peak traffic continuously increased between 2012 and 2017, as did average traffic, probably at a similar rate to the peak traffic. Hence, the average traffic is likely to be equal to the peak traffic at an earlier date, as illustrated in Figure 11. Combined with supplementary information on market share, I could aggregate this to the national level. Due to confidentiality, I cannot divulge the exact calculations and source data.

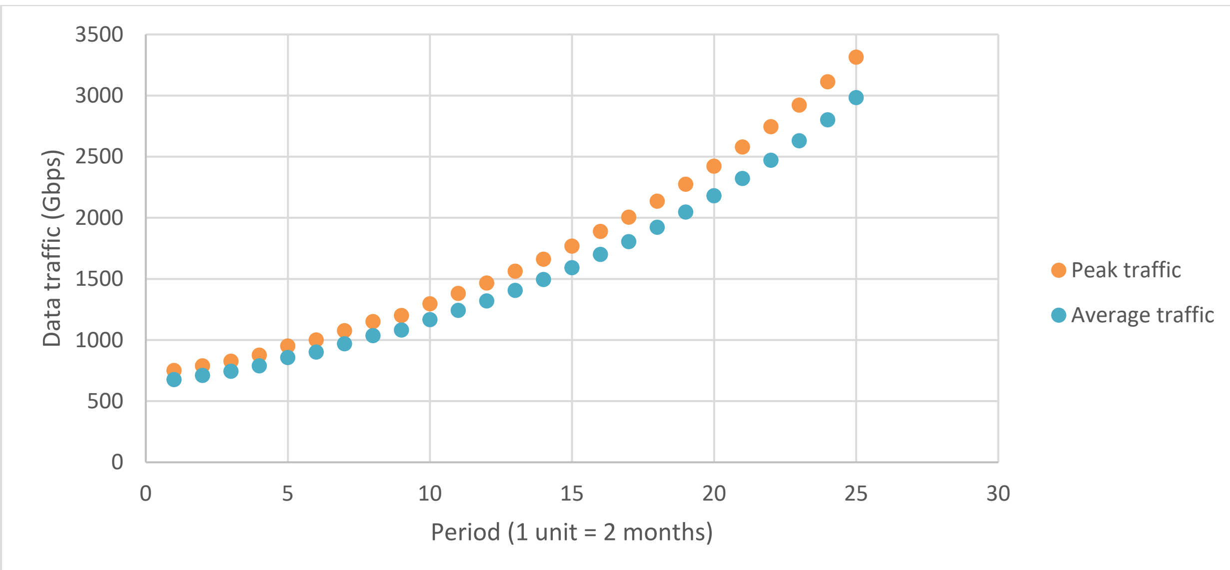

Figure 11: The relation between peak and average broadband traffic.

The traffic data included both private and professional subscribers. Private subscribers are natural persons, i.e. data traffic not related to professional or official use. Private subscriptions make up 94% of the market and consume most of the data. However, it is unlikely that the distribution of data traffic is identical to the market share. For cellular data traffic, we have better data. In 2012, 83% of all mobile data traffic was from private subscribers. In 2017 the share increased to 86%. I applied the same ratio to fixed broadband traffic, and estimated average per capita traffic from private subscribers, resulting in 48 and 172 GB / month per capita for 2012 and 2017 respectively. This corresponds well with numbers from the US, where a study found that monthly use between May and June 2012 was 50 GB / month for subscribers with unlimited plans (Nevo, Turner, & Williams, 2016, p. 417).

In addition, I had to include mobile traffic. I obtained this information from NKOM by combining data traffic from mobile phones (mobile data traffic) and mobile broadband (Norwegian Communications Authority, 2019). For 2012, there data traffic from mobile phones was unavailable, this was estimated using regression based on data from 2012-2018. Adding the different types of traffic, I was able to estimate the total data traffic from private subscribers, i.e. data usage for leisure activities, as shown in Table 15.

Table 15: Annual per capita internet traffic from private subscriptions, 2012 and 2017.

Traffic type	Data traffic per capita, 2012 (1000 GB)	Data traffic per capita, 2017 (1000 GB)
Fixed broadband	2,869,991	10,863,602
Mobile data traffic	7,292	121,234
Mobile broadband	11,017	64,315
Total	**2,888,299**	**11,049,151**

The energy use per GB of data traffic occurs at several points along the data pipeline. These are both direct and indirect. We have already looked at the demand side, the consumer devices that receive the data. On the supply side, the ISPs and data centres are filled with servers, switches, hubs and routing equipment. In between are the satellites, fibre optic cables, copper wires, and cellular towers that transmit the data (Costenaro & Duer, 2012). There are several estimates in academic literature, differing in scope, as illustrated in a literature review by Aslan, Mayers, Koomey, and France (2018). Based on this review, I choose to use the estimates provided by Malmodin and Lundén (2018). This estimate is well suited, as it covers 2007, 2010 and 2015, and only covers energy use in networks. The latter is important to avoid double accounting, as I have already covered user devices using LCA data. Using curve fitting, I estimated energy intensity as 1.9 MJ/GB for 2012 and 0.5 MJ/GB for 2017. I multiplied the respective energy intensities with the data traffic, with the resulting energy use in Table 16.

Table 16: Energy use from internet traffic in Norway, 2012 and 2017.

Traffic type	Energy use, 2012 (TJ)	Energy use, 2017 (TJ)
Fixed broadband	5,453	5,432
Mobile data traffic	14	61
Mobile broadband	21	32
Total	**5,488**	**5,525**

4.2.3. Content production

There are two types of content related to this category. The first is software for different purposes, from system software necessary for managing the device, e.g. the operating system of a computer, to applications that perform specific tasks, e.g. word processors or games. The other category is online media content. The production of both involve energy use.

The LCAs I have used for equipment does not specifically include software, but the study includes results for GHG emissions on a global scale based on the estimates, with approximately 700 $MtCO_2eq$ as the low estimate (Belkhir & Elmeligi, 2018). This corresponds well to the 730 $MtCO_2eq$ estimated by Malmodin and Lundén (2018) that does include software. This indicates that the first does include software, or that the software component has relatively low impact. Based on this, I did not make any attempts to include the energy use from software.

Estimating the energy use involved in content production for the internet is difficult as well. A lot of content is not exclusive to the internet, even if available on the internet. Books are still available in book stores, you can still visit the cinema to watch a movie or follow a TV-series on a linear schedule. In 2001, this was the case for most content, but this has changed with time. As an example, YouTube first came online in 2005, and is, at least in principle, based on user generated content that is only available online. Netflix is another. In 2011, they began acquiring original content, i.e. movies and series produced to cater to the streaming market.

For free content, such as YouTube videos, I assume that energy use should be allocated to the supply side, e.g. the sites hosting the content and the people making it. This is where the economic activity is, and this triggers the environmental loads. If you make a video from riding your bike down a mountainside, it is one of your leisure activities. The direct and indirect energy use from buying the bike, the camera, driving to the location and so on is triggered by you. If I get money from a ski wax producer to produce and publish a tutorial video on waxing skis, these are processes related to the production and sales of wax company.

For paid content, such as a Netflix or Amazon Prime subscription, input-output analysis offers the possibility of calculating emissions, provided that the sector or product in the IO-table accounts for this. Publishing content for digital distribution rather than physical products has different environmental impacts as different processes are involved. As an example Mayers et al. (2015, p. 413) suggest that downloading a digital game involves the same emissions as purchasing a physical disc, but that this changes if the consumer uses public transport and combines game purchasing with other shopping. The IO-table I have used for this thesis, does include a category for video and audio media. As mentioned, it is based on data from 1996, before streaming services were available, and is likely to give inaccurate results. More importantly, streaming services replace physical formats of the same media, such as CDs and Blu-ray discs. These belong to the “audio and video devices” category in Hille et al. (2007).

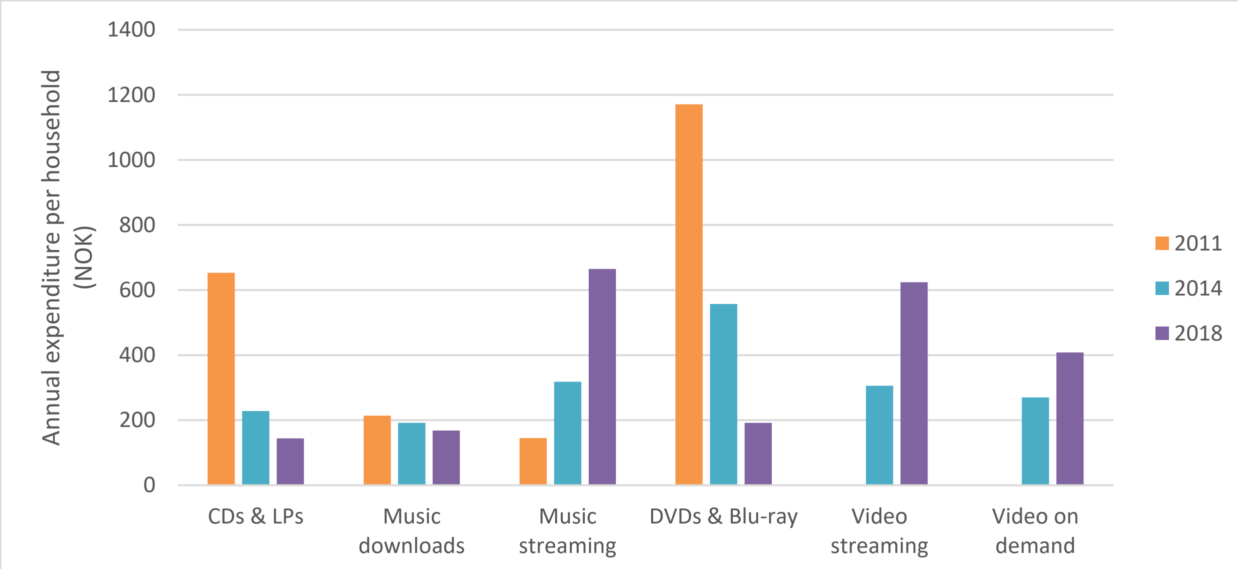

Figure 12: Average household expenditures for audio and video media in Norway (Jortveit, 2015, 2019; Mackhé, Anshelm, & Jortveit, 2011).[11]

To keep consistent with the 2001-results, I did not include energy use for content production. This is also logical, as the environmental loads and economic activity generated by the consumption of media is related to the subscription fee, rather than the actual data traffic.

4.2.4. Total energy use and energy intensities

Combining the results from Table 14 and Table 16, I found that the total energy use from IT and internet in Norway was 10,520 TJ in 2012 and 11,066 TJ in 2017.

As mentioned, Statistics Norway provide annual statistics on media use, including digital games, internet and computers (Statistics Norway, 2019b). The last two activities are somewhat ambiguous, overlap is likely, and since 2015, Statistics Norway no longer provide separate data for computer use. Based on this, I have based my estimation on the numbers reported for digital games and internet use, which should cover most leisure use. Norwegian residents spent 3,427 million hours on IT and internet in 2012, and 5,822 million hours in 2017. Based on this, I found that energy use per hour was 3.07 MJ/hour in 2012 and 1.90 MJ/hour in 2017.

In the case of expenditures, the consumer expenditure survey provide data for equipment purchases for 2012. For subscription fees and software purchases, I used supplementary data from Kantar's consumer expenditure survey for 2011 (Mackhé et al., 2011), as this offers more resolution. As annual changes in expenditure are likely to be small relative to the changes in energy use, I did not adjust the 2011 numbers. For 2017, I used survey data from Kantar for all expenditures, as there is no other data available (Jortveit, 2019). These data are from 2018 but were not adjusted following the same reasoning as above. This resulted in 0.47 MJ/NOK for 2012 and 0.40 MJ/NOK for 2017.

[11] DVDs & Blu-ray includes both rental and sales. The last video rental in Oslo closed in 2016 (Lilleby, 2016). Video on demand (VOD) covers online video rental available via TV providers such as Altibox or Canal Digital.

4.2.5. Summary and evaluation of IT and internet-based recreation

The results indicate that the environmental load of IT and internet-based recreation has remained stable between 2001-2017. This is due to the technological gains in efficiency (Belkhir & Elmeligi, 2018; Malmodin & Lundén, 2018). However, advances in technology have only kept up with the increase in demand. While there are limits to how much time consumers can spend on these activities, and we still can expect hardware improvements, the studies suggest that the increase in demand outpaces the gains, at least on a global scale (Aebischer & Hilty, 2015). According to Santarius (2016), this is due to a rebound effect; the technological advances enable social and economic acceleration, ultimately causing an increase in energy demand. In other words, to reduce energy use, increased efficiency is not enough, growth needs to be decelerated to reduce the environmental load. Device manufacturers and service providers all need to generate revenue. This can be achieved through accelerating or intensifying the consumption, i.e. decreasing the time per consumed unit, or increasing the consumption per time unit.

At the equipment side, the continuous replacement of devices explains the lack of reduction. There are two main reasons for this. First, electronic devices have a limited lifetime. The components do not last forever, and there is a continuous need for improved capacities, e.g. processing power and storage. Second, the introduction of new devices leaves older products less desirable. This is an area where the market seems to be adjusting on its own. On the supply side, vendors increasingly offer second-hand devices, and offer rebates if old devices are handed in, both in line with the concept of a circular economy. The solution provides manufacturers with an economical and sustainable source of materials, creates a new revenue stream for the vendor, saves money for the consumer, and is beneficial for the environment. This trend is likely to continue as the deposits providing some of the minerals used in the production of electronic devices are under pressure, with marginal costs increasing as a result (Dominish et al., 2019).

On the traffic side, the increase in data flows negates the efficiency gains, with streaming of video as the main driver. The number of unicasts are increasing, i.e. unique data streams to each user as opposed to multicasts where several users follow the same data stream. In addition, the quality, e.g. video resolution, has improved giving higher data use per stream (Ø. Vevang, personal communication, 15 February 2019). This corresponds with data from the United States. For one ISP, the share of data traffic related to video increased from 34 to 61% between 2012 and 2015, which is a 260% increase in data traffic (Nevo et al., 2016, p. 416). ISPs can benefit from this, as increased data flows require more bandwidth, while streaming services can use increased quality to both attract new subscribers and increase the prices for existing ones.

Due to its low energy intensities, IT and internet-based recreation may appear as an environmentally preferable alternative to other activities. Norwegians already spend considerable amounts of time streaming movies, playing games, on social media and similar activities. The results indicate that growth has occurred, and may only occur, at the expense of other activities. However, while devices may be pricey, services are cheap, often free. As a result, a shift towards IT and internet-based recreation may save money for consumers. These funds may be spent on products and services that are less beneficial to the environment, but further studies are required to identify such effects. Conversely, when it comes to policy measures, the Norwegian government has a stated policy to facilitate for data centres (Statsministerens kontor, 2019). Secure delivery of clean hydropower is the main selling point, with the Ministry of Trade, Industry and Fisheries stating that Norwegian energy production is without purchasing costs and emissions (2018), i.e. environmental impacts from imported energy, construction of new power plants or maintenance of existing ones is externalised.

4.3. Outdoor recreation

Outdoor recreation differs from the other two activities due to data availability. Energy use in outdoor recreation is mainly related two equipment and mobility. As previously mentioned, there are two main sources for these data, but as opposed to the other two activities, there is little supplementary data. There is also a lack of data related to the production and maintenance of facilities, as facilities include everything from commercial marinas and ski resorts to trail networks for hiking and mountain biking maintained by volunteers. The only available statistics are based on the allocation of the surplus earned by Norsk Tipping, the state-owned gaming company (Breivik & Rafoss, 2017; Kulturdepartementet, 2016).

It is also necessary to define which activities belong to the outdoor recreation category. Official documents from the Norwegian government define outdoor recreation as spending leisure time and engaging in physical activities in open air, with the purpose of a change of surroundings and experiencing nature (Klima- og miljødepartementet, 2016, p. 10). This is a wide definition, but it corresponds well with the activities Hille et al. (2007) included in their definition: skiing, hiking, cycling, boating, fishing, hunting and the gathering of mushrooms and berries.

4.3.1. Equipment for outdoor recreation

From the 1970s until today, outdoor recreation has gone from a few core activities to a high degree of diversification (Klima- og miljødepartementet, 2016). Norwegians no longer just go skiing. Ski sailing, ski mountaineering and freeriding are all styles of skiing that involve different equipment. Mountain bike is no longer a clear-cut term. XC bikes are used for gravel and less challenging trails, while full suspension downhill bikes allow the rider to quickly descend steep and technical tracks. Most activities also have specific clothes, footwear, eyewear and protective equipment. These all belong to different categories according to COICOP, and thus in consumer expenditure surveys and IO-tables. Sportsbransjen AS, a Norwegian industry association, have annual data on sales of sports and outdoor equipment, but only at an aggregate that includes sport specific equipment and athleisure wear[12].

Based on this, and for the sake of consistency, I have included the same consumption categories as Hille et al. (2007). These are “major durables for recreation”, “hire, maintenance and repair of major durables for recreation”, “, “equipment for sport, camping and open-air recreation” and “bicycles”. The category for sports, camping and open-air recreation equipment includes items for gymnastics, physical education, and game-specific foot- and sportswear, such as skis, balls, firearms, and protective gear. Some of these items fall outside the scope of outdoor recreation, while others are used for both sports and outdoor recreation. Once again, I followed Hille et al. (2007), and assigned 90% of the expenses to outdoor recreation. While they based this on a guess, it is not an unlikely estimate. According to a study on physical activity, Norwegian residents prefer outdoor recreation to organized sports (Breivik & Rafoss, 2017). While they limit outdoor recreation to hiking and cross-country skiing, their findings indicate that resource intensive activities such as cycling, other forms of skiing, and sailing, which I define as outdoor recreation, are more widespread than competitive or organized forms of sports. I also allocated 90% of

[12] Athleisure is when garments designed for outdoor recreation or sports is used casually, e.g. at school, work or when going out.

the expenses for hire, maintenance and repair to outdoor recreation, as these costs are likely associated with camper vans and boats. In 2013/14, Norwegians used bikes for transportation for 0.15 daily trips, with an average distance of 5.1 kilometres. This corresponds to 1170 million kilometres per year. Assuming a speed of 15 km/h, this amounts to 3 minutes per day (Hjorthol et al., 2014). From the time-use survey, we know that Norwegians in ages 5-79 on average spent a minute per day for recreational cycling. With a speed of 15 km/h, this equals 375 million kilometres in total (Statistics Norway, 2012). As such, it could be argued that a lower share should be assigned to outdoor recreation. However, I did not find data on bike ownership, but it is reasonable to assume a fair share of crossover, i.e. bikes used for both purposes, and that bikes specifically designed for outdoor recreation are more expensive than bikes intended for transportation. Based on this, I assumed an equal share of expenses between outdoor recreation and mobility purposes such as commuting to work. This also corresponds with the results from cluster analysis of the survey data. According to this analysis, bike commutes constitute about half of the daily trips (Ellis, Amundsen, & Høyem, 2016, p. 22). These allocations are consistent with Hille et al. (2007).

To calculate the embodied energy in outdoor equipment, I aggregated the average expense per household with the number of households in Norway in 2012, and combined these with the corresponding IO-data, as shown in Table 17.

Table 17: Indirect energy use from outdoor recreation equipment purchased in Norway, 2012

Consumption category	**Average household expenditure (NOK)**	**Total expenditure from Norwegian households (Mill. NOK)**	**Energy intensity (MJ/NOK, ref. A.1)**	**Energy use (TJ)**
Major durables for recreation	3,291	7,326	0.6193	4,536
Hire, maintenance and repair of major durables for recreation	194	431	0.6193	267
Equipment for sport, camping and open-air recreation	1,701	3,787	0.6193	2,345
Bicycles	442	984	0.3851	355
Total				**7,337**

As noted, there are no data on household expenditures for 2017. However, Statistics Norway offer data on imports. Figure 13 displays imports related to outdoor recreation as defined in this thesis. The figure does not include clothes or shoes for outdoor recreation, as these are impossible to discern from the data. The import of boats has been stable between 2012 and 2017, while the import of goods for sport and recreation has increased by 16%. This indicates a similar increase in indirect energy use. Since these are imported goods, this likely involves a substantial amount of embodied carbon.

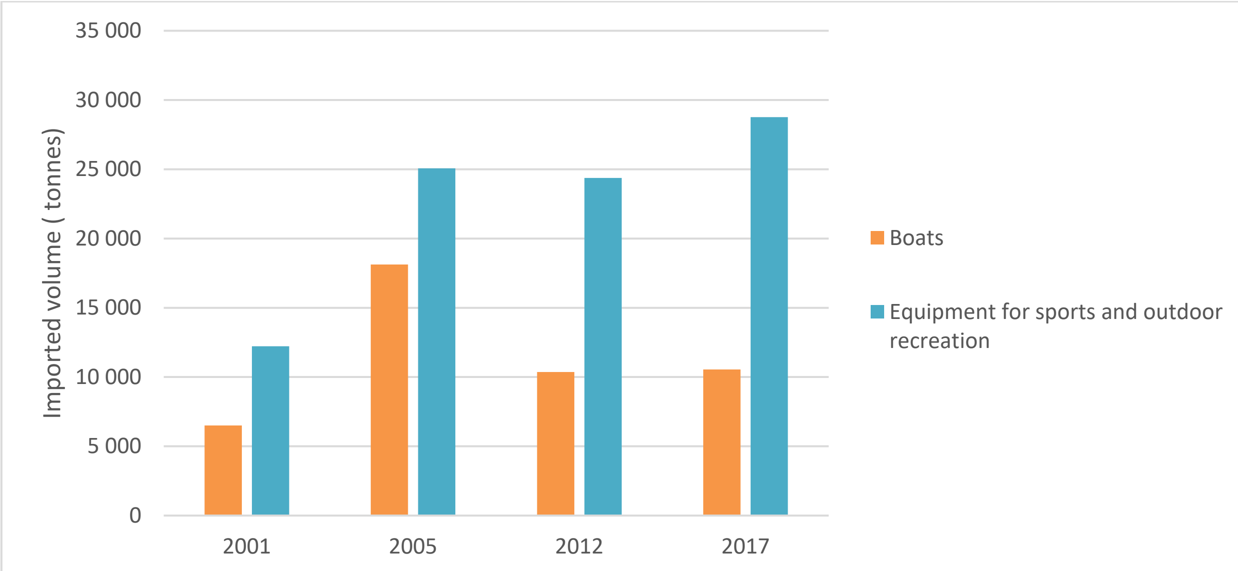

Figure 13: Import of boats and equipment used for sports and recreation, including recreational fishing (Statistics Norway, 2019i).[13]

4.3.2. Use of equipment

The IO-data used to calculate the energy use from equipment includes energy in the use phase. However, there is one exception, and that is fuel used for boats, as this belongs to another consumption category according to COICOP. According to survey reports commissioned by the Royal Norwegian Boat Association, Norwegian residents bought 1,323 million Norwegian kroners worth of fuel in 2011 and 1,522 million kroner in 2017 (Kongelig Norsk Båtforbund, 2012, 2018). To find the volume in cubic metres, I assumed that the same 24/76 distribution as Bang did in 1996 (Hille et al., 2007, p. 78). In 2011 duty-free diesel had an average price of 9.48 NOK/l, and petrol 13.95 NOK/l. Combining these values, I calculated a consumption of 33,873 tonnes of diesel and 71,820 tonnes of petrol for recreational boating in 2011. Using the same approach for 2017, I calculated a consumption of 28,626 tonnes of diesel and 58,259 tonnes of petrol. Following the approach described in A.1 Conversions from final to primary energy, I calculated a total primary energy use of 4,620 TJ in 2011 and 4,924 TJ in 2017. With only two data points, it was difficult to specify a result for 2012, but I assumed linear growth, which gives an energy use of 4,696 TJ in 2012.

[13] Imported goods follow the HS-nomenclature from the World Trade Organization. The following correspond to the outdoor recreation category in this thesis: HS 89.03 = Yachts and other vessels for pleasure and sports; HS 95.06 = Articles and equipment for general physical exercise, gymnastics, athletics, other sports or outdoor games; HS 95-07 = Fishing rods, fish-hooks and other line fishing tackle.

4.3.3. Production, maintenance and operations of facilities

In a sense, outdoor recreation is not site specific. Any open-air location offering contact with nature and a change of scenery fits the bill. This also includes some developed venues such as ski resorts[14], ski tracks[15], marinas, and purpose-built trails[16].

In the case of marinas and ski resorts, the energy used for construction is likely significant. There are countless commercial and private harbours and similar facilities for recreational boating in Norway. When it comes to ski resorts and ski lifts, 629 facilities are registered by the Norwegian Ministry of Culture. This is an improbable number, and a review of the data indicate a considerable amount of duplicates (Kulturdepartementet, 2016). This occurs because each facility that receives a government grant from the lottery surplus gets registered, even if operated by the same organization and placed at the same location. A better estimation is the 203 destinations that are members of Alpinanleggenes Landsforening (ALF).[17] In total, these destinations cover 95% of the turnover in Norwegian ski resorts (Alpinanleggenes Landsforening, 2019). I was unable to find acceptable data for construction and maintenance for such locations. As a result, the energy use from construction and maintenance of destinations for outdoor recreation has been neglected. This gives a less accurate result, but remains consistent with the 2001-results from Hille et al. (2007). It should be noted that such locations have long economic lives and high usage. This means that the resulting energy use per activity is relatively low.

For operations, hiking trails and marinas are expected to have low energy use, and these have been neglected. For ski tracks and ski resorts, the picture is different, as energy is used for lighting, snow production, and the grooming of tracks and slopes.

Snow grooming of cross-country ski tracks and ski resorts

Grooming is necessary, i.e. manipulating the snow for recreational purposes, for both ski tracks and slopes and is mostly done with snow groomers. There are approximately 850 snow groomers in use in Norway (Brav Norge AS, 2019), including large groomers used for slopes, and smaller groomers used for ski tracks. According to O. K. Hole Olsen, who runs a web site for snow grooming in Norway, large groomers run at 15 km/h with a diesel consumption of 22 l/h. Small groomers run at 20 km/h with a fuel consumption of 10-12 l/h. Snow groomers have life expectancy of ten years and run approximately 600 hours per year, and sales indicate an equal share between large and small groomers (personal communication, 9 April 2019). Based on this, I calculated total fuel consumption, and converted this to primary energy use as described in A.1 Conversions from final to primary energy. This gave a result of 354 TJ per year, as shown in Table 18. This result is applicable for both 2012 and 2017, as the number of snow groomers in use has been stable (O. K. Hole Olsen, personal communication, 9 April 2019). To cover the use of snowmobiles as well as the production and maintenance of snow groomers and snowmobiles, Hille et al. (2007) added 111 TJ of primary energy. There is no information on how they

[14] Ski resorts are defined as destinations with ski lifts and slopes for alpine skiing, telemark, snowboarding and similar activities.
[15] Ski tracks are defined as waymarked tracks for cross-country skiing, normally specified in maps. These may be groomed to fit narrow skis, or just regularly maintained with markers. Of course, any area covered in sufficient amounts of snow can be used for skiing.
[16] Purpose-built trails are paths and tracks that have been waymarked, cleared, or otherwise developed to accommodate hiking, mountain biking, roller skiing or similar activities.
[17] Alpinanleggenes Landsforening is the Norwegian industry association for ski resorts.

arrived at this number, neither did I find better data. Hence, I added the same amount of energy, giving a total energy use of 465 TJ for grooming.

Table 18: Primary energy use for grooming of ski tracks and slopes in Norway.

Grooming area	Number of machines	Speed (km/h)	Running hours per year	Diesel consumption per hour (l)	Diesel consumption per year (m3)	Primary energy use (TJ)
Ski tracks	425	20	600	11	2,805	129
Ski slopes	425	15	600	22	5,610	225
Total						**354**

Illumination of cross-country ski tracks

To calculate energy used for illuminating cross-country ski tracks, I had to identify the total length of tracks. From the values in Table 18, I calculated that there 25.500 kilometres groomed double tracks in Norway, assuming that each track is prepared once per day in a 100-day season. This corresponds well with the 24.839 kilometres of active tracks registered at Skisporet.no (Brav Norge AS, 2019). However, only a share of these tracks are fitted with lighting, and as reported by Hille et al. (2007, pp. 79-80), it is difficult to get a good estimate. There are 1,228 existing facilities that have received government funding specifically designated as illuminated trails, including hiking trails. I included the latter, as these might be used for skiing during the winter, and in either case, they are used for outdoor recreation. Assuming an average length of five kilometres, this gives a total of 6,140 kilometres of floodlit trails. S. Bergtun Auganæs from SIAT, NTNU's Centre for Sport Facilities and Technology, suggested 30 metres between masts and 120 watts per fixture (personal communication, 9 April 2019). This wattage corresponds well to metal-halide and high-pressure sodium fixtures suggested for floodlit trails (Senter for idrettsanlegg og teknologi, 2018). Due to regulations banning fixtures containing PCB and mercury-halide, government grants and cost-saving opportunities, LED-fixtures are becoming more widespread (Garathun, 2014; Rosenborg, 2014), but this was still uncommon in 2012. Using these values, I found an installed capacity of 24.56 MW. The next step was to determine running hours. There are large temporal and geographical variations in natural lighting and hours of operation, I had to simplify. I did this by assuming hours of operation between 06:00 and 22:00. To avoid waste of energy, I assumed that astronomic timers or sensors are used, e.g. lights are off during daylight hours and at nights. Since 94% of the facilities are designated specifically for skiing (Kulturdepartementet, 2016), I assumed that they are only operated between November and April. Based on astronomical tables, this gives an average of 7.5 running hours per day in southern Norway, and 10 hours in the north. I assumed an 80/20 distribution of ski tracks between the regions, resulting in 8 running hours per day. I assumed a season of 100 days. Based on this, I calculated a final energy use of 71 TJ. This was converted to primary energy as explained in A.1 Conversions from final to primary energy, with a result of 108 TJ. In recent years, old lights have been replaced with more efficient LED fixtures, typically 30 watts. Assuming 50% replacement in 2017, I calculated the energy use to 68 TJ.

Snow production for cross-country ski tracks

Producing snow for a double cross-country ski track requires 2400 m^3 of snow per kilometre of trail, and you need 3.5 kWh of energy to produce a cubic metre of snow. The amount of snow produced in a year depends on the weather, and there are large variations between locations from year to year. A cold winter with little snow may require just as much production as a warm winter with large amounts of snow. A Swedish study assumed an average production of 7,500 m^3 of snow per ski track, and that 100 tracks used snow production, and conditions are likely to be similar in Norway (S. Bergtun Auganæs, personal communication, 9 April 2019). This gives 2.5 GWh / year in final energy, which equals 14 TJ of primary energy.

Ski resort operations

For ski resorts, I have already covered energy use from fossil sources, i.e. grooming. That leaves electricity for running ski lifts, lights, snow production and other support functions in the resorts. There are no public data sources providing this information, but SkiStar[18] provided me with data for electricity consumption, as shown in Figure 14 (A. J. Ellbro, personal communication, 8 May 2019). As indicated in the figure, energy electric energy consumption is relatively stable, except for 2017. This spike may be caused by snow production, as there the snowfall in December and February was relatively modest (Skiinfo.no, 2019), and snow production can have significant impact on the annual energy use in a ski resort.

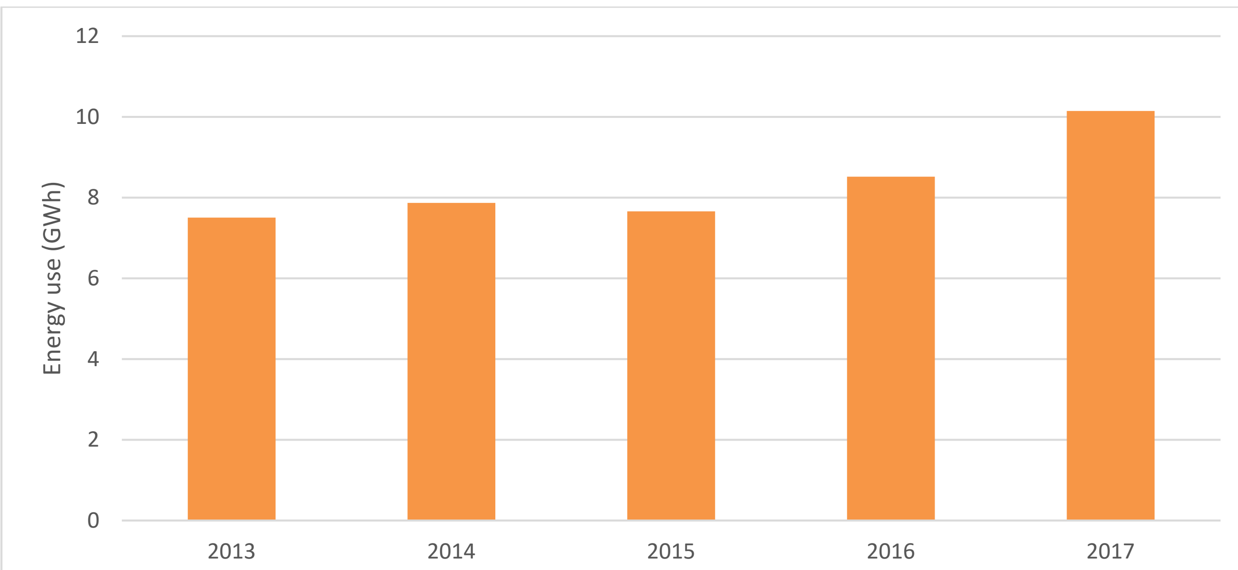

Figure 14: Energy consumption at Trysilfjellet ski resort, 2013-2017.

Trysilfjellet has a market share of 15%, a share which has been consistent since 2013. Based on this, I aggregated the data to the national level, converted this to primary energy. This gave a primary energy use of 288 TJ in 2013 and 359 TJ in 2017. Of course, using the energy use from a single resort increases the uncertainty of this estimate, especially considering the effect of snowfall and temperature on energy used for snow production. According to C. Sylling Claussen, secretary general of ALF, the energy use may vary significantly from year to year and between locations and correlation with skier days is weak

[18] SkiStar is a Swedish company that owns and runs several alpine resorts. They own two alpine resorts in Norway, three in Sweden and one in Austria.

(personal communication, 2 April 2019). Hence, the energy use in 2012 might be lower than in 2013, or on par with 2017. Based on this, I allocated the average of the 2013 and 2017 results, which is 324 TJ.

Adding all these results together, I found that the production, maintenance and operation of facilities required 587 TJ of primary energy, as shown in Table 19. This result depends more on weather conditions than other factors. The major difference between 2012 and 2017, is the energy used for lighting, as old fixtures are being replaced. Further reductions may be achieved through more efficient snow groomers and snow production, but this may be more than nullified by increased temperatures in the long run.

Table 19: Energy use for the operation of ski facilities.

Component	Energy use (TJ)	
	2012	2017
Grooming (cross-country skiing and ski resorts)	465	465
Lighting (cross-country skiing)	108	68
Snow production (cross-country skiing)	14	14
Ski resort operations	324	324
Total	**911**	**871**

4.3.4. Daily trips for outdoor recreation

Transportation for outdoor recreation can include everything several types of travel, from plane rides to distant destinations to short walks to areas close to home. In this category, I only include daily trips. That leaves travels of longer durations, including trips to cabins and vacation destinations, where the outdoor recreation may be the sole purpose of the travel. In the case of holiday trips by airplane, this is already covered. These are not included as they belong in activity categories not described in this thesis.

As described earlier, the national travel survey is the main source on the travel habits of Norwegian residents. Hille et al. (2007, pp. 80-82) considered alternate approaches to estimate travel associated with outdoor recreation, but these involve substantial margins of error, and data has availability has not improved since then. In fact, the 2013/14 survey offer less detail, as travels related to “other leisure and recreation” has been replaced with categories for travels related to hiking, jogging and marinas. The survey covers several modes of transport, but we only need those related to motorized transport. Since fuel use related to boats is covered elsewhere, I excluded travels by boat as well. Using the dataset from the survey, I used SPSS to find average trip distance for daily travels in these categories, as well as the share and average daily trips for each mode of transport (TNS Gallup, 2016). The survey only covers people aged 13 and up. I aggregated the data to cover the entire population (Statistics Norway, 2019g). According to the travel survey, daily travel habits have been relatively stable, hence I applied the 2013/14-numbers for 2012 without adjustment (Hjorthol et al., 2014, p. 33).

Energy intensities were taken from Vestlandsforsking (2016). This database covers several fuel types for different vehicles. This database cover vehicles that run on different forms of energy, from fossil fuels to electricity. I combined these intensities with data on the fleet composition of buses and cars in Norway by fuel type (Statistics Norway, 2019h), to get weighed intensities representative of each category. Finally, the survey data has separate categories for both car drivers and passengers. This poses a potential allocation problem, which is solved according by defining zero energy use for passengers while using the intensity per vehicle kilometre for drivers (Hille et al., 2007, p. 82). Finally, I combined these data to calculate the energy use, as shown in Table 20.

Table 20: Primary energy use for transportation related to outdoor recreation, 2012.

Mode of transport	PKM (Millions)	Energy intensity (MJ / pkm)	Energy use (TJ)
MC / moped	48	1.52	72
Car driver	1269	3.04	3853
Car passenger	313	0	0
Bus	112	1.61	182
Tram	2	1.18	2
Subway	12	1.35	17
Train	59	1.32	78
Total			**4,203**

4.3.5. Total energy use and energy intensities

In total, the energy use for outdoor recreation in 2012 was 12,805 TJ, with equipment purchases and transportation as the largest components. I was unable to calculate the total energy use for 2017, due to missing data on equipment purchases and travel habits

Based on the time-use survey, Norwegians spent 349 million hours on leisure activities in 2012 (Statistics Norway, 2012). This gives an energy use per hour of 49 MJ.

To calculate the total expenses for outdoor recreation, I used data from the consumer expenditure survey (Statistics Norway, 2013). These were combined with separate calculations for transportation expenses, where I multiplied the data from Table 20 with costs provided in Table A-3. Results are shown in Table 21. This gives an energy use of 0.65 MJ per NOK.

Table 21: Expenses for outdoor recreation, 2012.

Type of expense	Expenses (Million NOK)
Equipment for outdoor recreation	12,527
Fuel for boats	1,323
Tickets for resorts / facilities	4,513

Type of expense	Expenses (Million NOK)
Public transport	236
Car	6,322
MC / moped	1,203
Total	**26,134**

4.3.6. Summary and evaluation of outdoor recreation

The results suggest that equipment purchases had the largest environmental. This was also the case in 2001. Next came fuel used for recreational boating, closely followed by transportation. The results are similar for all three years. These results are in stark contrast to the concept of outdoor recreation in the Norwegian tradition, where the intrinsic value of nature is one of the key concepts, and expensive equipment and specific arenas are unnecessary (Faarlund et al., 2007, p. 393). To reduce the load, consumers need to change behaviour.

Studies suggest several reasons why Norwegians regularly purchase new equipment. Technical advances makes old equipment seem cumbersome and unsafe, and is perceived as offering improved experiences, and as already mentioned activities have introducing new categories of specialized equipment (Aall et al., 2011; Klima- og miljødepartementet, 2016, p. 23). On the supply side, several companies such as Patagonia and Bergans, have already taken steps towards a more circular economy by focusing on repair, reuse, resales and recycling (Gairns & Rønnevik, 2018). For such initiatives to succeed, the consumer must get engaged. According to Ingun Grimstad Klepp, who has performed several studies on clothing in Norway, Norwegians tend to keep their old outdoor gear as reserves when they purchase new items (personal communication, 7 December 2018). This reduces the potential market for second-hand equipment.

The second significant component was fuel for boats, and it has been suggested that faster, larger and water scooters have become more common (Klima- og miljødepartementet, 2016, p. 52). In the case of recreational boating, electrification is a viable option, as switching to electric powertrains will reduce both energy consumption and emissions, and the energy need is relatively low. Another option is the introduction of environmental fees on the purchases of motorized boats. This has been previously suggested in an Official Norwegian report but has yet to be introduced (NOU 2015: 15, 2015, p. 20).

The third was the daily trips associated with outdoor recreation. While the impact is significant, it should be noted that cycling and walking, which is not included in the results, far surpass motorized travels in volume. While motorized transport was used for 87 million daily trips in 2012, people walked or rode bikes for a total of 821 million trips if daily walks are included (TNS Gallup, 2016). Arguably, this indicates that Norwegians avoid using motorized transport for when participating in outdoor recreation activities, but when they do, they drive a car. Equipment should be used for longer periods, and this may be achieved through a circular economy. The best way to reduce this impact is to further facilitate for walking and cycling, and to either penalize driving or incentivizing public transport. The latter corresponds to policy measures in place by the government, such as toll roads where revenue is used to build pedestrian lanes and bicycle paths. Similarly, municipalities and voluntary organizations such as sporting clubs and the Norwegian Trekking Association run campaigns to promote activities close to home.

4.4. Compilation and evaluation of the results

To provide the necessary level of detail, the results are compiled in two tables. Table 22 shows the time use, expenditures, energy use and energy use per hour / NOK for the selected activities in 2012. The results at the component level have been excluded from this table, as they are shown in Table 23. The 2001-results from Hille et al. (2007) are presented in full in Appendix B.

Table 22: Energy use and energy intensities for selected activities in 2012.

Consumption category	Time use (million hours)	Expenditures (million NOK)	Energy use (TJ)	Energy use (MJ)	
				Per hour	Per NOK
Holiday trips by air	1,173	25,495	63,109	51	2,6
IT & internet-based recreation	3,427	22,230	10,520	3	0,4
Outdoor recreation	349	26,134	17,070	49	0,65
Total / average	**4,949**	**73,859**	**90,699**	**34**	**1,2**

The results for 2012 show that travelling on holiday with an airplane consumed the most energy in 2012. It was also the most energy intensive of the three consumption categories, both in time and money. To put this in context, we can compare the energy use with other measures of energy consumption and production in Norway, as illustrated in Figure 15. This indicates that in 2012, the energy used for these activities equalled 17% of the total renewable energy production, 21% of the total electric energy consumption across all sectors, and 56% of the total household energy consumption in Norway that year. Since a large share of this energy is derived from fossil fuels, where aviation is the main contributor, a corollary of this is that decarbonization through electrification will either require importing energy, or the construction of new power plants for renewable energy production. Considering that these activities only cover three categories of leisure consumption, the total requirement is considerably higher. From the 2001-results we know that visiting friends, family and cabin trips are categories that also consume considerable amounts of energy derived from fossil fuels. While modern technology may have reduced social visits, statistics on cabins indicate that cabins have become increasingly popular (Statistics Norway, 2019m).

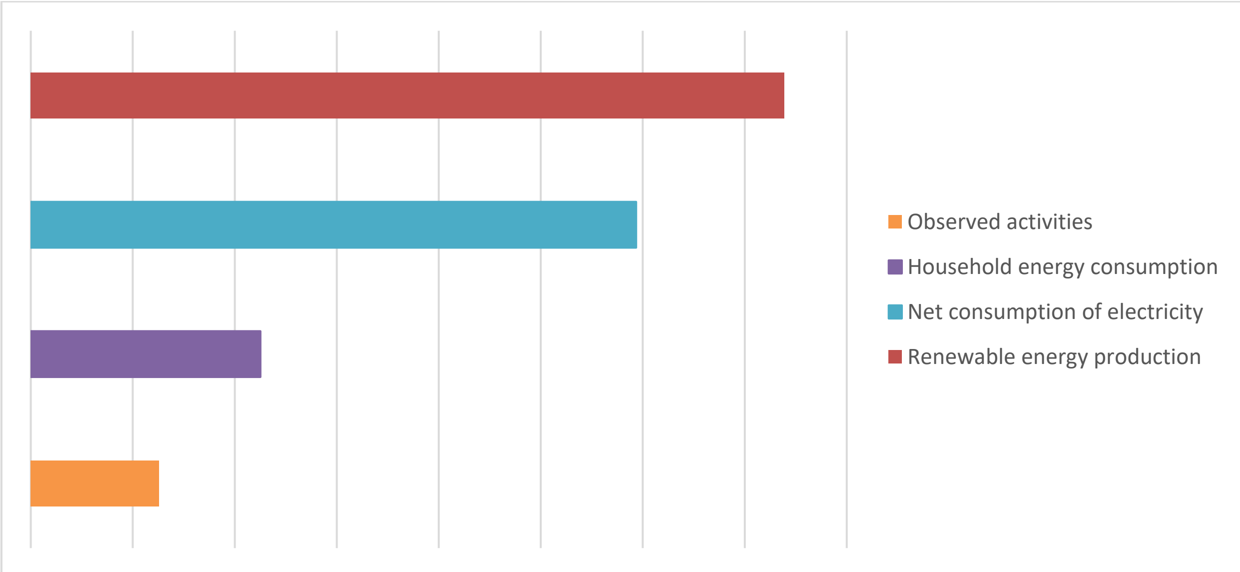

Figure 15: Comparison of energy use in Norway, 2012.

Table 23 provide results at the component level for 2001, 2012 and 2017. Totals are not included, as I was unable to calculate this for each category. The results are incomplete, and there are some inaccuracies. Hille et al. (2007) only provides numbers on lodgings for holiday trips with all types of transportation. The accommodation energy use in 2001 was recalculated based on the share of air travel and average trip duration (Hille et al., 2007, pp. 48-56). For 2017, there was insufficient data to estimate energy use. However, based on supplementary sources I evaluated if the energy use had increased (+), decreased (-), or remained stable (=), as indicated in the table and commented below.

Table 23: Final energy use at the component level for selected consumption categories, 2001-2017.

Consumption category	Component	Energy use (TJ)		
		2001 (Hille et al., 2007)	2012	2017
Holiday trips by air	Air travel (domestic)	844	2,761	3,121
	Air travel (abroad)	29,989	46,977	46,960
	Accommodation (domestic)	60	3,358	+
	Accommodation (abroad)	4,141	10,014	= / -
IT & internet-based recreation	Equipment	9,731	5,032	5,541
	Internet traffic	1,874	5,488	5,525
Outdoor recreation	Equipment purchases	5,789	7,337	+

	Fuel for recreational boating	3,078	4,696	4,924
	Operation of ski tracks and resorts	895	911	871
	Transportation	6,267	4,203	-

Air travel surveys provide us with some indications for vacations abroad. In 2011, long stays (8 days or more) or more comprised 42% of all holiday trips by air. In 2003, the share had been 52%. Short stays (1-3 days), e.g. weekend trips, and medium stays (4-7 days) both increased their shares in the same period (Denstadli & Rideng, 2012, p. 45). This indicates that the revised energy estimates for accommodation in 2001 are too low, and unusable for comparison. Between 2011 and 2017 medium stays gained ground at the expense of both short and long stays (Thune-Larsen & Farstad, 2018, p. 45). Concomitant, there was only a slight increase in the number of trips. This indicates a stable or slight decrease in energy use for travels abroad. For domestic holiday trips, there was a 19% increase in trips between 2012 and 2017. For hotels, there has been an increase in energy efficiency in this period (Table 10), and the same may apply for other lodging types as well. However, if the 3% efficiency gain for hotels is an indicator, this is far outweighed by the increased volume of trips.

As noted in 4.3.1, imports of sports and outdoor recreation equipment increased by 16% between 2012 and 2017. The production of this type of equipment in Norway is limited, almost everything is imported. Based on this, the increase in import indicates a similar increase in energy use, i.e. approximately 1,170 TJ. When it comes to transportation, two supplementary sources offer some insight. The survey on living conditions indicate a slight decrease in the participation in outdoor recreation activities (Statistics Norway, 2018c). We also know that those living in the most populated cities (Oslo, Stavanger, Bergen and Trondheim) are least likely to use cars for daily trips related to leisure activities (Hjorthol et al., 2014, p. 59). These cities, and their surrounding municipalities, are also the same areas where electric vehicles were most common in 2017 (Statistics Norway, 2019h). This suggests that this energy use for transportation has remained stable or decreased.

Plotting the results in a bar chart, as shown in Figure 16, clearly indicate that the environmental load from holiday trips increased between 2001 and 2012. While the 2001-estimate is low, as described earlier, this only applies to the accommodation component, and the aviation component alone had an increase of 57%. Between 2012 and 2017 the environmental load appears to have stabilized. For the two other categories, the results indicate that the environmental load has remained stable throughout the period. While the 2017-results for outdoor recreation and holiday trips are based on guesstimates based on the assumptions described above, it is improbable that the actual load was significantly higher or lower.

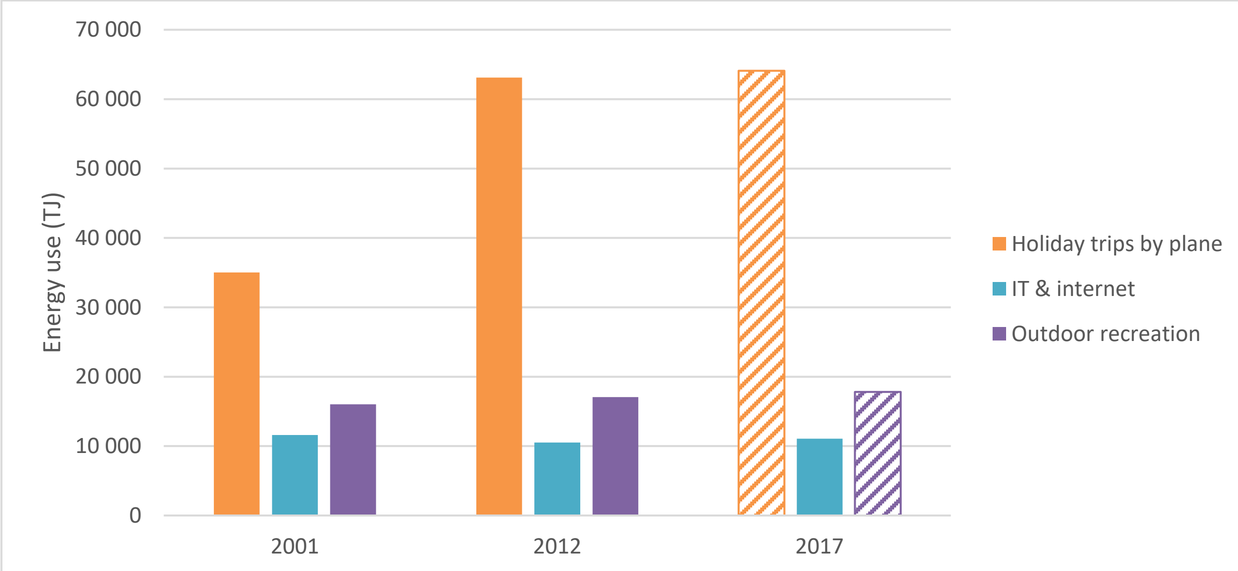

Figure 16: Energy use from observed activities, 2001-2017.

Between 2001 and 2017, the population in Norway increased. The population growth was 10.7% between 2001 and 2012 and 5.5% between 2012 and 2017. The population increase between 2001 and 2012 does not correlate with the growth in holiday trips by air, neither does it correlate with the minor changes for the two other consumption categories. The same applies between 2012 and 2017. Since the observed trend of stabilization does not correspond with changes in the population, that leaves two other explanations, consumer behaviour on the demand side, or mitigation through technology, innovation or policy on the supply side (Dubois et al., 2019). Changes on the supply side have already been addressed, and in the case of IT and internet use, it is an important factor. Concomitant, based on efficiency gains in this category alone, the energy use should have subsided. That leads us to consumer behaviour.

Change in consumer behaviour can occur due to numerous causes. As an example, researchers have suggested that internet booking services have contributed to cheaper and shorter holiday trips (Gössling, Aall, Nilsson, & Gyimóthy, 2019). At the same time, fears over climate change, has caused people to rethink how they travel, and there are words for the shame associated with flying in Sweden, Finland, Holland and Germany (Piskorz, 2019).

However, all leisure consumption requires two resources, time and money, and the abundance of these resources set boundaries for consumer behaviour. In compliance with the idea of perpetual economic growth, which is central to how the Norwegian economy is arranged, there are, in theory, no limits to the levels of disposable income. Of course, there are no limits to market prices either. In other words, there are limits to how much money each consumer can spend on leisure activities from day to day, but in the long run, the market can grow. This is true, provided we can decouple production from resource use and / or availability, e.g. producing more with less. However, on the demand side, there is one resource with an absolute limit, and that is time. No matter how much money you have, you can only spend so much time travelling to exotic destinations, surfing the internet, or ski mountaineering.

My results indicate that Norwegian leisure consumption is approaching one or both limits. Statistics show an increase in disposable income with a simultaneous reduction in time worked between 2001 and

2017. Reduced working hours does not necessarily translate to increased leisure time. However, data from time-use surveys indicate this has been the case. Between 2000 and 2010, leisure time increased by eight minutes for Norwegian residents' average day, i.e. 45 minutes per week (Vaage, 2012). This correlates well with the 48 minute decrease in the actual work week from the labour force survey (Statistics Norway, 2019c). There are no more recent data on leisure time, but between 2010 and 2017 the actual work week has remained relatively stable, with a variance of 1.4 minutes.

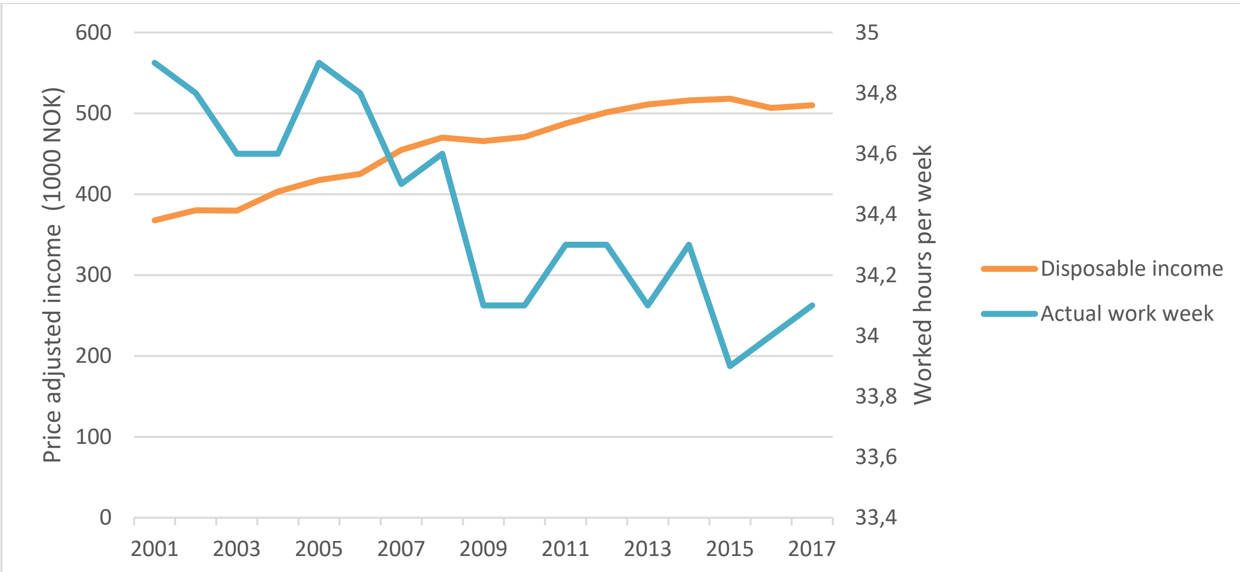

Figure 17: Actual work hours per week and inflation adjusted average disposable income per household (Statistics Norway, 2018b, 2019c).

This suggests that temporal restraints played a lesser part between 2001 and 2012. However, the most significant change in leisure time use between 2000 and 2010 was related to IT and internet-based leisure activities, with a 21 minutes increase on an average day. This is more than the total increase in available leisure time, and less time was spent on other activities, namely visits to restaurants / cafés, visiting friends and family, parties and conversations. People did not spend more time on holiday trips. In fact, on an annual basis, people spent six hours less on leisure travel (Vaage, 2012). From this we can assume that: 1) time was a limiting factor in this period as well, and 2) there was a change in consumer behaviour, e.g. social media replaced other forms of social interaction. The latter has another implication as well. Since the use of digital media is relatively cheap, it offers the possibility of savings. In addition, internet based services give consumers access to cheaper goods and services (DIBS, 2017; Gössling et al., 2019). This can explain why there was an increase in holiday trips by plane between 2001 and 2012. It also suggests that price matters, and that there is a pecuniary limit.

The statistics imply no increase in leisure time between 2012 and 2017. We can thus assume that the temporal limit is still in effect. The results also show that people use more time on IT and internet-based activities. This should impact the time spent on other activities, but the available data do not reveal which activities this might be, and to what extent. Since there is no expenditure survey we cannot discern if the monetary limit plays a bigger part, but statistics do not indicate that Norwegians have become more frugal (Figure 18). A survey on E-commerce supports this. Norwegian consumers shop online because it is convenient and time saving, not because they save money on it (DIBS, 2019).

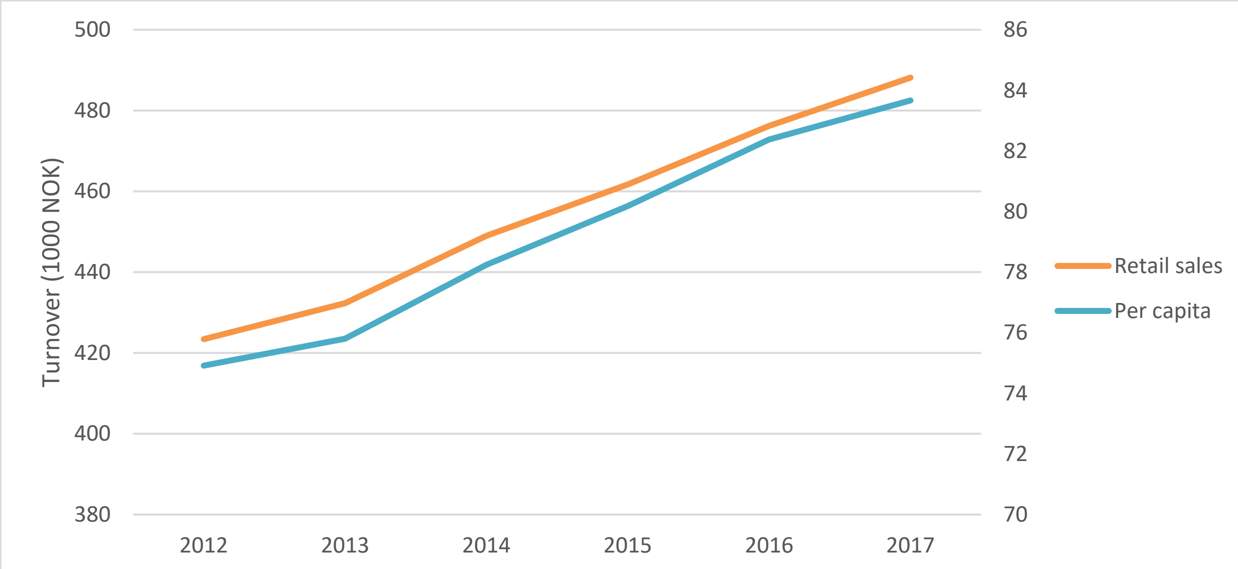

Figure 18: Turnover in Norwegian retail sales, total and per capita, 2012-2017 (Statistics Norway, 2019d, 2019f).

In summary, the findings suggest that temporal limits have a significant impact on Norwegian residents' leisure consumption. There are financial constraints as well, but this appears to have less impact. However, it is difficult to separate cause and effect. This is important for two reasons. First, it indicates that an increase in one category can only happen at the expense of another category. While I have only investigated three categories of consumption, it is unlikely that other activities have a higher impact than holiday trips, barring home renovation, which was the most energy intensive activity per hour in 2001. However, energy intensity per NOK was relatively low, indicating that funds freed from other activities are unlikely to increase the overall environmental load. As such, all changes away from holiday trips by air will be favourable. Furthermore, the low energy intensities for IT and internet-based recreations suggest that all shifts towards such activities will subside the total environmental load. Second, it suggests that the environmental load may increase if Norwegian residents get more free time, provided there is no simultaneous reduction in wages. This is contrary to what is suggested by a Swedish study (Nässén & Larsson, 2015).

By definition, the estimates from three specific consumption categories in a specific economy cannot be generalized. Differences in demography, the national economy and geography are all examples of factors in play. Germans may go on vacations abroad just as much as Norwegians do, but the infrastructure is vastly different, and trains is a more practical option in Germany than in Norway. Britons may be more frugal than Norwegians when buying gear for hiking and camping. People in Greece may not enjoy the same internet availability as Norwegians do, and cultural differences may leave them less inclined to substitute real life interaction with social media. Hence, separate studies are required, and these may be difficult to produce if the data availability is poor. To produce the results in this thesis, I had to consult a plethora of sources. Barring a few exceptions, I could not use data from statistical sources directly into calculations. In some cases, no data was available at all. I have commented this in the results chapter, but this has further implications, especially regarding consumption data. The consumer expenditure survey was published annually from 1974 to 2009. In 2011 it was decided that the survey should be performed periodically at different intervals. The first of these was performed in 2012. It was also the last. Expenditure surveys are crucial when estimating environmental loads from consumption using IO-tables. The latest study on emissions from household consumption in Norway uses data from 2012 (Steen-Olsen et al., 2016). Updated expenditure data would facilitate updated numbers, enabling longitudinal comparison. This would be invaluable to determine the environmental effects of supply and demand side changes, e.g. consumer trends or policy measures. The lack of specific data on digitization efforts, from the consumption of data traffic to the average number of devices in Norwegian households, makes it difficult to determine how this paradigm shift affects the environment. The same applies to international aviation to and from Norway. While academic studies may illustrate how the flight habits of Norwegian residents affect the environment, these are harder to produce today than before.

5. Conclusion

I began this thesis by asking some questions about the environmental load of Norwegian leisure consumption. The main question was what the load from holiday trips by air, IT and internet-based activities and outdoor recreation is in Norway. To answer this, I also wanted to identify the changes, if any, in the environmental loads from these activities between 2001 and 2017. Finally, I wanted to find which factors contributed to the environmental loads from these consumption categories, and how the effect could be lessened. These questions can be answered by three points. First, the answer to the main research question is that the environmental load is relatively high. The three leisure categories consume energy equal to 56% of Norwegian households' energy consumption, and 17% of the renewable energy consumption in Norway. Second, the results indicate few changes in the environmental load for the selected activities, except for holiday trips between 2001 and 2012. This does not signify no changes in consumption, rather the opposite. Lest there had been a significant increase in IT and internet-based recreation, the environmental load from this category had subsided considerably. This suggests the emergence of the internet has caused a shift in Norwegians' time-use, reducing the potential for growth in other categories. It appears this shift has been favourable, as IT and internet-based recreation has low energy intensities, each hour and crown diverted from other activities reduces the environmental load. This implies that the consumption, and hence the environmental load, is governed by boundaries of time and money, where the availability of time is the most important. Norwegians appear to consume what they can when they can, and it appears Norwegians are approaching the limits of leisure consumption, at least within the three selected activities. Third, transportation, and aviation in particular, is the most important factor in driving the environmental load, followed by the incessant equipment purchases. For aviation, the solution is simple. The distances and energy use involved clearly indicate that electric airplanes are a non-viable option, at least within 2030, the first milestone in the Climate Act. People need to fly less frequently for vacations. When they do, distances should be shorter, preferably within Europe, and they should spend more time at the destination. For equipment purchases, be it smartphones or kayaks, the transition to a circular economy offers possibilities where both suppliers and consumers may benefit while reducing the environmental load.

These three points may not be epiphanies, they only confirm what theory tells us. However, they provide a sketch of the situation, and some policy recommendations are apparent. At the government level, policy makers must acknowledge that theories on economic growth does not account for finite resources or natural sinks. While reducing emissions is tantamount, it cannot necessarily be combined with economic growth in the traditional sense. When crafting policy to reduce GHG emissions, the ecological footprint of the measure must be considered as well.

On the supply side, consumers have to make more informed choices, they need to know what the right choice is. In other words, the consumers need to be aware of the environmental impacts of their consumption. This is not a novel idea. There are marking schemes for a range of products, from foods to dishwashers, that inform the consumer on production standards, energy use, environmental standards and so forth. For foodstuffs, the nutritional facts provide the user with detailed information relevant to health. These marking schemes could easily be applied to a further range of products and inform the user the exact emissions or ecological impact of a product. To achieve this, further studies on the impacts of leisure activities are necessary.

However, consumers can not be tasked with the responsibility of changing on their own. There must be co-operation with the supply side. Products and services need to be designed from a cradle-to-grave perspective, with as low an environmental impact as possible. Products should be designed for long technical lives, facilitating repair, furbishing and recycling services. The market for providing these services should be strengthened. This will inevitably make these goods and services more expensive. Policy makers should craft regulations that give sustainable products a competitive edge. This can be achieved through a combination of subsidies and taxes, such as with electric vehicles in Norway, or carbon fee and dividend such as in Canada. Both approaches have a potential pitfall of increased consumption. This can be addressed through national policy by reducing working hours provided wages are reduced accordingly.

Further research is required to gauge the environmental load and better inform a policy on sustainable leisure. The relationship between leisure activities and environmental impact is dynamic. If you stop flying tomorrow, you will save some money. You may use the savings to buy a train ticked instead, or you may buy a new bike. Even if you leave the money in your bank account, they will have an impact. The bank may lend them to someone keener on consuming. To keep track of this, future updates on the environmental impacts of leisure activities in Norway are necessary. To facilitate the production of such reports, I recommend three studies. The first should an environmentally extended input-output analysis for the Norwegian economy, and at the subclass level of COICOP. The second is a detailed study of IT-use internet traffic in Norway at the subscriber level, including what the data is used for, e.g. gaming, streaming et cetera, and device ownership. The third, and final suggestion, is a detailed study on the environmental impact of outdoor recreation at the activity level.

6. References

Aall, C., Klepp, I. G., Engeset, A. B., Skuland, S. E., & Støa, E. (2011). Leisure and sustainable development in Norway: part of the solution and the problem. *Leisure Studies, 30*(4), 453-476. doi:10.1080/02614367.2011.589863

Aamaas, B., & Peters, G. P. (2017). The climate impact of Norwegians' travel behavior. In (pp. 10-18).

Aebischer, B., & Hilty, L. (2015). The Energy Demand of ICT: A Historical Perspective and Current Methodological Challenges. *Advances in Intelligent Systems and Computing, 310*, 71-103. doi:10.1007/978-3-319-09228-7_4

Alpinanleggenes Landsforening. (2019). Alpinanleggenes Landsforening (ALF). Retrieved from http://www.alpinanleggene.no/om-alpinanleggenes-landsforening-informasjon/alpinanleggenes-landsforening

Archer, D., Eby, M., Brovkin, V., Ridgwell, A., Cao, L., Mikolajewicz, U., . . . Tokos, K. (2009). Atmospheric Lifetime of Fossil Fuel Carbon Dioxide. *Annual review of earth and planetary sciences, 2009*(37), 117-134.

Aslan, J., Mayers, K., Koomey, J. G., & France, C. (2018). Electricity Intensity of Internet Data Transmission: Untangling the Estimates. *Journal of Industrial Ecology, 22*(4), 785-798. doi:10.1111/jiec.12630

Avinor. (2013a). *Månedsrapport desember 2012* [Dataset]. Retrieved from: https://avinor.no/konsern/om-oss/trafikkstatistikk/arkiv

Avinor. (2013b). *Passasjerer 2012* [Dataset]. Retrieved from: https://avinor.no/konsern/om-oss/trafikkstatistikk/arkiv

Avinor. (2018a). Månedsrapport desember 2017.

Avinor. (2018b). *Passasjerer 2017* [Dataset]. Retrieved from: https://avinor.no/konsern/om-oss/trafikkstatistikk/arkiv

Bakken, T. H., Sundt, H., & Ruud, A. (2012). *Mange og små eller store og få?* (TR A7180). Retrieved from https://www.cedren.no/Portals/Cedren/Publications/TR_A7180_FINAL.pdf

Belkhir, L., & Elmeligi, A. (2018). Assessing ICT global emissions footprint: Trends to 2040 & recommendations. *Journal of cleaner production, 177*, 448-463. doi:10.1016/j.jclepro.2017.12.239

Berglund, M. (2018). *Consumption-based data from the PRINCE project* [Dataset]. Retrieved from: http://prince-project.se/wp-content/uploads/PRINCE-Excel-tool-2018-11-29.xlsx

Brav Norge AS. (2019, 20 May 2019). Skisporet.no. Retrieved from https://skisporet.no/

Breivik, G., & Rafoss, K. (2017). *Fysisk aktivitet; omfang, tilrettelegging og sosial ulikhet*. In. Retrieved from https://www.helsedirektoratet.no/rapporter/fysisk-aktivitet-kartleggingsrapporter/Fysisk%20aktivitet;%20omfang,%20tilrettelegging%20og%20sosial%20ulikhet%202017.pdf

Brundtland, G. H., & Dahl, O. (1987). *Vår felles framtid*. Oslo: Tiden norsk forlag.

Carnegie Mellon University Green Design Institute. (2008). Economic Input-Output Life Cycle Assessment (EIO-LCA). Retrieved from http://www.eiolca.net

Costenaro, D., & Duer, A. (2012). *The megawatts behind your megabytes: going from data-center to desktop.* Paper presented at the ACEEE Summer Study on Energy Efficiency in Buildings.

Cox, B., Jemiolo, W., & Mutel, C. (2018). Life cycle assessment of air transportation and the Swiss commercial air transport fleet. *Transportation Research Part D: Transport and Environment, 58*, 1-13. doi:https://doi.org/10.1016/j.trd.2017.10.017

Cross, G. (1993). Time, Money, and Labor History's Encounter with Consumer Culture. *Inter. Labor Working-Class Hist., 43*, 2-17. doi:10.1017/S0147547900011789

Daly, H. E. (1991). *Steady-State Economics* (2nd ed.). Washington, D.C.: Island Press.

Denstadli, J. M., & Rideng, A. (2012). *Reisevaner på fly 2011* (1209/2012). Retrieved from https://www.toi.no/getfile.php/1324142/Publikasjoner/T%C3%98I%20rapporter/2012/1209-2012/1209-sammendrag.pdf

Denstadli, J. M., Thune-Larsen, H., & Dybedal, P. (2014). *Reisevaner på fly 2013* (1335/2014). Retrieved from https://www.toi.no/getfile.php?mmfileid=36898

DIBS. (2017). *Norsk E-handel 2016*. Retrieved from https://info.dibs.no/norsk-e-handel-2016

DIBS. (2019). *Norsk E-handel 2018*. Retrieved from https://info.dibs.no/norsk-ehandel-2018

Dominish, E., Florin, N., & Teske, S. (2019). *Responsible Minerals Sourcing for Renewable Energy.* Retrieved from https://earthworks.org/cms/assets/uploads/2019/04/MCEC_UTS_Report_lowres-1.pdf

Dubois, G., Sovacool, B., Aall, C., Nilsson, M., Barbier, C., Herrmann, A., . . . Sauerborn, R. (2019). It starts at home? Climate policies targeting household consumption and behavioral decisions are key to low-carbon futures. *Energy Research & Social Science, 52*, 144-158. doi:10.1016/j.erss.2019.02.001

Dæhlen, M. (2018, 17 July 2018). Nordmenn vil ikke slutte å fly, selv om vi vet det skader miljøet. *forskning.no*. Retrieved from https://forskning.no/transport-luftfart/nordmenn-vil-ikke-slutte-a-fly-selv-om-vi-vet-det-skader-miljoet/1190622

Ellis, I. O., Amundsen, M., & Høyem, H. (2016). *Utvikling og variasjon i sykkelomfanget i Norge. En dybdeanalyse av den norske reisevaneundersøkelsen.* (78/2016). Retrieved from https://www.sykkelbynettverket.no/fag/faglitteratur/reisevaneundersokelser/_attachment/1815635?_download=true&_ts=15b8571a408

Energifakta Norge (Producer). (2017). Kraftmarkedet. Retrieved from https://energifaktanorge.no/norsk-energiforsyning/kraftmarkedet/

Enevoldsen, P. (2018). A socio-technical framework for examining the consequences of deforestation: A case study of wind project development in Northern Europe. *Energy Policy, 115*, 138-147. doi:10.1016/j.enpol.2018.01.007

Enova. (2013). *Enovas Byggstatistikk 2012*. Retrieved from https://www.enova.no/download?objectPath=upload_images/4202FD4EEE7B4C988A71733FF3AFC5B9.pdf&filename=Enovas%20byggstatistikk%202012.pdf

Enova. (2018). *Enovas Byggstatistikk 2017*. Retrieved from https://www.enova.no/download?objectPath=upload_images/5C6245BC2AD74248BB629BFA95145AA3.pdf&filename=Enovas%20byggstatistikk%202017.pdf

European Commission. (2016). Nearly zero-energy buildings. Retrieved from https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/nearly-zero-energy-buildings

European Commission. (2019, 28 May). Nearly Zero Energy Hotels (neZEH). Retrieved from https://ec.europa.eu/energy/intelligent/projects/en/projects/nezeh

Faarlund, N., Dahle, B., & Jensen, A. (2007). *Nature is the home of culture - friluftsliv as a way home.* Paper presented at the Science and stewardship to protect and sustain wilderness values: Eight World Congress Symposium, Fort Collins, Colorado.

Fontana, L., Atella, V., & Kammen, D. M. (2013). Energy efficiency as a unifying principle for human, environmental, and global health. In (pp. 101).

Gairns, A., & Rønnevik, J. S. (2018, 21 November). Bergans, bærekraft og Black Friday. *Harvest.* Retrieved from https://www.harvestmagazine.no/artikkel/bergans-baerekraft-og-black-friday

Garathun, M. G. (2014, 5 December). 2015 kan bli mørkt: 120.000 lysarmaturer må skiftes ut. *Teknisk ukeblad*. Retrieved from https://www.tu.no/artikler/2015-kan-bli-morkt-120-000-lysarmaturer-ma-skiftes-ut/225408

Global Footprint Network. (2019). Ecological Footprint Explorer. Ecological Footprint Explorer Retrieved 1 May 2019 http://data.footprintnetwork.org/#/

Gössling, S., Aall, C., Nilsson, J.-H., & Gyimóthy, S. (2019). Airbnb og Booking.com har gjort det lettere og billigere å reise, men flere turister er ikke det samme som verdiskapning. *forskning.no*. Retrieved from https://forskning.no/internett-kronikk-turisme/airbnb-og-bookingcom-har-gjort-det-lettere-og-billigere-a-reise-men-flere-turister-er-ikke-det-samme-som-verdiskapning/1279975

Hertwich, E. G., & Peters, G. P. (2009). Carbon Footprint of Nations: A Global, Trade-Linked Analysis. *Environmental Science & Technology, 43*(16), 6414-6420.

Hille, J. (2015). *Litt om nordmenns utanlandsreiser og utviklinga frå 2006 til 2013/2014. Forsøk på oppdatering av tala i rapporten om Miljøkonsekvenser av norsk forbruk og produksjon.* Unpublished. Vestlandsforsking. Sogndal.

Hille, J., & Aall, C. (2010). Consumption - a missing dimension in climate policy. In *Interdisciplinarity and Climate Change* (pp. 85-100). London: Routledge.

Hille, J., Aall, C., & Klepp, I. G. (2007). *Miljøbelastninger fra norsk fritidsforbruk - en kartlegging* (1/07). Retrieved from https://www.vestforsk.no/sites/default/files/migrate_files/rapport-1-07-fritidsbruk.pdf

Hille, J., Storm, H., Aall, C., & Sataøen, H. (2008). *Miljøbelastningen fra norsk forbruk og norsk produksjon 1987-2007* (2/2008). Retrieved from https://www.vestforsk.no/sites/default/files/migrate_files/miljobelastningen-fra-norsk-forbruk-og-produksjon-1987-2007.pdf

Hjorthol, R., Engebretsen, Ø., & Uteng, T. P. (2014). *Den nasjonale reisevaneundersøkelsen 2013/14: nøkkelrapport* (1383/2014). Retrieved from https://www.toi.no/getfile.php?mmfileid=39511

Høie, H., Kolshus, K., & Køber, T. (2015). Hvilke utslipp dekkes av statistikkene. *Statistisk sentralbyrå*. Retrieved from https://www.ssb.no/natur-og-miljo/artikler-og-publikasjoner/hvilke-utslipp-dekkes-av-statistikkene

IPBES. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Advance unedited version.* Retrieved from https://www.ipbes.net/sites/default/files/downloads/spm_unedited_advance_for_posting_htn.pdf

IPCC. (2018a). Annex I: Glossary. In J. B. R. Matthews (Ed.), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5° above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global resoonse to the threat of climate change, sustainable development, and efforts to eradicate poverty.* (pp. 541-562). In press.

IPCC. (2018b). Summary for Policymakers. In V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Mouforma-Okia, R. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, C. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, & T. Waterfield (Eds.), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (pp. 1-32). Geneva, Switzerland: World Meteorological Organization.

Jalas, M., & Juntunen, J. K. (2015). Energy intensive lifestyles: Time use, the activity patterns of consumers, and related energy demands in Finland. *Ecological Economics, 113*, 51-59.

Jortveit, S. (2015). *Husholdningens medieutgifter 2014. Hva betaler norske husholdnigner for ulike medieprodukter og -tjenester?* Oslo: Kantar.

Jortveit, S. (2019). *Husholdningens Medieutgifter 2018* [Dataset].

KGM & Associates. (2018). *National CBA Report 1970-2015* [Dataset]. Retrieved from: https://worldmrio.com/footprints/carbon/national.cba.report.1970.2015.txt

Klima- og miljødepartementet. (2016). *Friluftsliv. Natur som kilde til helse og livskvalitet.* (Meld. St. 18 (2015-2016)). Retrieved from https://www.regjeringen.no/no/dokumenter/meld.-st.-18-20152016/id2479100/sec1.

Klimaloven. (2017). Lov om klimamål (LOV-2017-06-16-60). Retrieved from https://lovdata.no/dokument/NL/lov/2017-06-16-60?q=klimaloven

Kok, R., Benders, R. M. J., & Moll, H. C. (2006). Measuring the environmental load of household consumption using some methods based on input–output energy analysis: A comparison of methods and a discussion of results. *Energy Policy, 34*, 2744-2761.

Kongelig Norsk Båtforbund. (2012). *Båtllivsundersøkelsen 2012. Fritdsbåtlivet i Norge*. Retrieved from https://knbf.no/images/Presentasjoner/KNBF_-_Rapport_komplett.pdf

Kongelig Norsk Båtforbund. (2018). *Båtlivsundersøkelsen 2018. Fritidsbåtlivet i Norge*. Retrieved from https://knbf.no/images/Presentasjoner/Hovedrapport_Nasjonal_2018.pdf

Kulturdepartementet. (2016, 1 March). Anleggsregisteret.no. Retrieved from https://www.anleggsregisteret.no/

Lacy, P., & Rutqvist, J. (2015). *Waste to Wealth: The Circular Economy Advantage*. New York, NY: Palgrave MacMillian.

Le Quéré, C., Andrew, R. M., Friedlingstein, P., Sitch, S., Hauck, J., Pongratz, J., . . . Canadell, J. G. (2018). Global carbon budget 2018. *Earth System Science Data (Online), 10*(4).

Lenzen, M., Kanemoto, K., Moran, D., & Geschke, A. (2012). Mapping the structure of the world economy. *Environmental Science & Technology, 46*(15), 8374-8381. doi:10.1021/es300171x

Lenzen, M., Kanemoto, K., Moran, D., & Geschke, A. (2013). Building Eora: A Global Multi-regional Input-Output Database at High Country and Sector Resolution. *Economic Systems Research, 25*(1), 20-49. doi:10.1080/09535314.2013.769938

Leontief, W. (1936). Quantitative Input and Output Relations in the Economic Systems of the United States. *The Review of Economics and Statistics, 18*(3), 105-125.

Leontief, W. (1970). Environmental Repercussions and the Economic Structure: An Input-Output Approach. *The Review of Economics and Statistics, 52*(3), 262-271.

Lilleby, J. (2016, 24 April 2016). Leietiden er over - nå stenger Oslos siste videobutikk. *E24*. Retrieved from https://e24.no/media/markedsfoering/leietiden-er-over-naa-stenger-oslos-siste-videobutikk/23664068

Lin, D., Hanscom, L., Murthy, A., Galli, A., Evans, M., Neill, E., . . . Wackernagel, M. (2018). Ecological Footprint Accounting for Countries: Updates and Results of the National Footprint Accounts, 2012–2018. In (pp. 58).

Mackhé, P., Anshelm, M., & Jortveit, S. (2011). *Den norske husholdningens medieutgifter*. Oslo: Kantar.

Malmodin, J., & Lundén, D. (2018). The energy and carbon footprint of the global ICT and E&M sectors 2010–2015. *Sustainability, 10*(9), 3027.

Maxton, G., & Randers, J. (2016). *Reinventing prosperity: Managing economic growth to reduce unemployment, inequality, and climate change*. Vancouver, BC: Greystone Books Ltd.

Mayers, K., Koomey, J., Hall, R., Bauer, M., France, C., & Webb, A. (2015). The Carbon Footprint of Games Distribution. *Journal of Industrial Ecology, 19*(3), 402-415. doi:10.1111/jiec.12181

Meadows, D., Randers, J., & Meadows, D. (2004). *Limits to growth: the 30-year update*. White River Junction, Vt: Chelsea Green Publishing.

Myhre, G., Shindell, D., Bréon, F.-M., Collins, W., Fuglestvedt, J., Huang, J., . . . Zhang, H. (2013). Anthropogenic and Natural Radiative Forcing. In T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, & P. M. Midgley (Eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the*

Interngovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Nevo, A., Turner, J. L., & Williams, J. W. (2016). Usage-Based Pricing and Demand for Residential Broadband. *Econometrica, 84*(2), 411-443. doi:10.3982/ECTA11927

Norwegian Communications Authority. (2019, 13 May 2019). Ekomstatistikken. Retrieved from https://ekomstatistikken.nkom.no/#/main

NOU 2015: 15. (2015). *Sett pris på miljøet. Rapport fra grønn skattekommisjon.* Retrieved from https://www.regjeringen.no/no/dokumenter/nou-2015-15/id2465882/sec1.

Nærings- og fiskeridepartementet. (2018). *Norge som datasenternasjon*. Retrieved from https://www.regjeringen.no/globalassets/departementene/nfd/dokumenter/strategier/strategi-nfd-nett-uu.pdf

Nässén, J., & Larsson, J. (2015). Would shorter working time reduce greenhouse gas emissions? An analysis of time use and consumption in Swedish households. *Environment And Planning. C, Government And Policy, 2015*(4), 726-745.

Peters, G. P., & Hertwich, E. G. (2006). Pollution in trade: The Norwegian case. *Global Environmental Change, 16,* 379-387.

Piskorz, J. (2019, 17 April 2019). How flygskam (or flight shame) is spreading across Europe. *London Evening Standard*. Retrieved from https://www.standard.co.uk/lifestyle/esmagazine/flight-shame-europe-sweden-a4120231.html

PRINCE project. (2018). Results from PRINCE. Retrieved from http://www.prince-project.se/results-overview/

Randers, J. (2012). *2052 : a global forecast for the next forty years : a report to the Club of Rome commemorating the 40th anniversary of The limits to growth*. White River Junction, Vt: Chelsea Green Publ.

Rosenborg, O. L. (2014, 7 November). Miljøfarlige skiløyper. *Østlendingen*. Retrieved from https://www.ostlendingen.no/ringsaker-blad/sport/vinteridrett/miljofarlige-skiloyper/s/2-2.2757-1.8645698

Rønnevik, J. S. (2019). *Gull og grønne skoger: Kartelgging av miljøbelastningene fra norsk fritidsforbruk*. Unpublished. Western Norway University of Applied Sciences.

Sandberg, T. (2019a, 13 May 2019). 150 ganger enklere å ta fly til kontinentet. *Dagsavisen*. Retrieved from https://www.dagsavisen.no/innenriks/150-ganger-enklere-a-ta-fly-til-kontinentet-1.1480108

Sandberg, T. (2019b, 6 May 2019). Heller fly enn Vy. Nordmenn er vesentlig mer fornøyde med flytilbudet enn togtilbudet. *Dagsavisen*. Retrieved from https://www.dagsavisen.no/innenriks/heller-fly-enn-vy-nordmenn-er-vesentlig-mer-fornoyde-med-flytilbudet-enn-togtilbudet-1.1476508

Sandmo, T. (2016). *The Norwegian Emission Inventory 2016 - Documentation of methodologies for estimating emissions of greenhouse gases and long-range transboundary air pollutants* (2016/22). Retrieved from Oslo:

Santarius, T. (2016). Energy efficiency and social acceleration: macro-level rebounds from a sociological perspective. In *Rethinking Climate and Energy Policies* (pp. 143-160): Springer.

Scientific Applications International Corporation. (2006). *Life Cycle Assessments: Principle and Practice* (EPA/600/R-06/060). Retrieved from Washington, DC: http://www.epa.gov/nrmrl/publications.html

Senter for idrettsanlegg og teknologi. (2018, 4 December). Langrenn. Retrieved from https://www.godeidrettsanlegg.no/verktoy/langrenn#title11

Simonsen, M. (2010). *Transport, energi og miljø* (2/2010). Retrieved from http://sip1.vestforsk.no/pdf/Felles/Sluttrapport.pdf

Skiinfo.no. (2019). Trysil Snøhistorikk. Retrieved from https://www.skiinfo.no/ostlandet/trysil/snohistorikk.html?y=0&q=snow

Skjervheim, Ø., & Høgestøl, A. (2017). *Norwegian Citizen Panel Methodology Report*. Bergen: University of Bergen.

Statistics Norway. (2012, 18 January 2012). Tidsbruksundersøkelsen. Retrieved from https://www.ssb.no/kultur-og-fritid/statistikker/tidsbruk/hvert-10-aar

Statistics Norway. (2013, 17 Marc 2013). Forbruksundersøkelsen 2012. Retrieved from https://www.ssb.no/inntekt-og-forbruk/statistikker/fbu

Statistics Norway. (2014). Gjennomsnittlig økonomisk levetid (antall år). Retrieved from https://www.ssb.no/nasjonalregnskap-og-konjunkturer/artikler-og-publikasjoner/ny-kartlegging-av-okonomisk-levetid-og-verdifall-for-realkapital?tabell=184994

Statistics Norway. (2018a). *03982: Innenlandsk persontransport, etter transportmåte 1965 - 2017* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/03982/

Statistics Norway. (2018b). *06076: Privathusholdninger og personer i privathusholdninger, etter statistikkvariabel og år* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/06076/

Statistics Norway. (2018c). *09116: Deltakelse på ulike friluftslivsaktiviteter siste 12 md. (prosent), etter friluftslivsaktivitet, ganger, kjønn, alder, statistikkvariabel og år* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/09116/

Statistics Norway. (2019a). *03014: Konsumprisindeks, etter konsumgruppe (2015=100) 1979 - 2018* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/03014/

Statistics Norway. (2019b). *04495: Tid brukt til ulike massemedier en gjennomsnittsdag (minutter) 1991 - 2018* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/04495/

Statistics Norway. (2019c). *04544: Sysselsatte i alt og i arbeid, utførte ukeverk (a 37,5 timer) og faktisk arbeidstid, etter kjønn og yrkesstatus 1996 - 2018* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/04544

Statistics Norway. (2019d). *04776: Omsetning per innbygger i detaljhandel (kr) (K) 2008 - 2018* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/04776/

Statistics Norway. (2019e). *05244: Andel som har tilgang til ulike medier og elektroniske tilbud i hjemmet (prosent), etter medietype, statistikkvariabel og år* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/05244/

Statistics Norway. (2019f). *07315: Omsetning for varehandel, etter næring (SN2007) (mill. kr) (F) 2008 - 2018*. Retrieved from: https://www.ssb.no/statbank/table/07315/

Statistics Norway. (2019g). *07459: Alders- og kjønnsfordeling i kommuner, fylker og hele landets befolkning (K) 1986 - 2019* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/07459

Statistics Norway. (2019h). *07849: Drivstofftype, type kjøring og kjøretøygrupper (K) 2008 - 2018*. Retrieved from: https://www.ssb.no/statbank/table/07849/

Statistics Norway. (2019i). *08801: Utenrikshandel med varer, etter varenummer (HS) og land 1988 - 2018* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/08801/

Statistics Norway. (2019j). *08940: Klimagasser, etter kilde, energiprodukt og komponent 1990-2017*. Dataset. Retrieved from: https://www.ssb.no/statbank/table/08940/

Statistics Norway. (2019k). *10799: Årlig inntekts- og kapitalregnskap (mill. kr.), etter sektor, transaksjon, statistikkvariabel og år* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/10799/

Statistics Norway. (2019l). *11561: Energibalanse. Tilgang og forbruk, etter energiprodukt 1990-2017* [Dataset]. Retrieved from: https://www.ssb.no/statbank/table/11561/

Statistics Norway. (2019m). Fakta om hytter og fritidsboliger. Retrieved from https://www.ssb.no/bygg-bolig-og-eiendom/faktaside/hytter-og-ferieboliger

Statsministerens kontor. (2019). *Granavolden-plattformen*. Retrieved from https://www.regjeringen.no/contentassets/7b0b7f0fcf0f4d93bb6705838248749b/plattform.pdf

Steen-Olsen, K., Wood, R., & Hertwich, E. G. (2016). The Carbon Footprint of Norwegian Household Consumption 1999-2012. *Journal of Industrial Ecology, 20*(3), 582-592.

The Norwegian Water Resources and Energy Directorate (Producer). (2017). Nasjonal varedeklarasjon 2016. Retrieved from https://www.nve.no/reguleringsmyndigheten-for-energi-rme-marked-og-monopol/varedeklarasjon/nasjonal-varedeklarasjon-2016/

The Norwegian Water Resources and Energy Directorate (Producer). (2018). Elektrifisering av transport gir nedgang i samlet energibruk. Retrieved from https://www.nve.no/nytt-fra-nve/nyheter-energi/elektrifisering-av-transport-gir-nedgang-i-samlet-energibruk/

The Norwegian Water Resources and Energy Directorate. (2019a). *Forslag til nasjonal ramme for vindkraft* (12-2019). Retrieved from http://publikasjoner.nve.no/rapport/2019/rapport2019_12.pdf

The Norwegian Water Resources and Energy Directorate. (2019b, 1 April). Oppdatert kunnskapsgrunnlag. Retrieved from https://www.nve.no/nasjonal-ramme-for-vindkraft/oppdatert-kunnskapsgrunnlag/

Thoring, L. (2017). *Den norske forbruksfesten* (12/2017). Retrieved from https://www.framtiden.no/aktuelle-rapporter/834-den-norske-forbruksfesten-1/file.html

Thune-Larsen, H., & Farstad, E. (2018). *Reisevaner på fly 2017* (1646/2018). Retrieved from https://www.toi.no/publikasjoner/reisevaner-pa-fly-2017-article35098-8.html

TNS Gallup. (2016). *Den nasjonale reisevaneundersøkelsen 2013/2014* [Dataset].

United Nations Statistics Division. (2018). *Classification of Individual Consumption According to Purpose (COICOP) 2018*. Retrieved from https://unstats.un.org/unsd/classifications/business-trade/desc/COICOP_english/COICOP_2018_-_pre-edited_white_cover_version_-_2018-12-26.pdf

United States Environmental Protection Agency. (2018). Greenhouse Gases Equivalencies Calculator - Calculations and References. Retrieved from https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

Vaage, O. F. (2012). *Tidene skifter. Tidsbruk 1971-2010*. Retrieved from Oslo: https://www.ssb.no/a/publikasjoner/pdf/sa125/sa125.pdf

Vestlandsforsking. (2016). Database som samanliknar energibruk og klimagassutslepp for ulike typar gods- og persontransport med bruk av ulike energikjelder. Retrieved 5 May 2019 http://transport.vestforsk.no/

Webb, A., Mayers, K., France, C., & Koomey, J. (2013). Estimating the energy use of high definition games consoles. *Energy Policy, 61*, 1412-1421. doi:10.1016/j.enpol.2013.05.056

Westskog, H., Selvig, E., Aall, C., Amundsen, H., & Jensen, E. S. (2018). *Potensial og barrierer for kommunale klimatiltak* (M-981). Retrieved from https://www.miljodirektoratet.no/globalassets/publikasjoner/M981/M981.pdf

Wiedmann, T. (2009). A review of recent multi-region input–output models used for consumption-based emission and resource accounting. *Ecological Economics, 69*(2), 211-222.

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., . . . Wood, A. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet, 393*(10170), 447-492.

Æra. (2017, 16 May 2017). Friluftsparadokset. *Floke.* Retrieved from http://floke.era.as/friluft

Appendix A: Source data from Hille et al. (2007)

In most cases, I used as recent data as possible for all estimations. In other cases, appropriate data were lacking. Finally, there in a few cases, the use of recent data had made comparison with the 2001-results problematic, as the recent data was based on fundamentally different system limits. When data has been lacking or incompatible with the 2001-results, I updated data from Hille et al. (2007), as described in this appendix.

A.1. Conversions from final to primary energy

When you charge your smartphone, travel by airplane, watch television or burn fuel in a camping stove, the energy you use is measured at the final level. It does not include the energy used in transport the energy to the end user. Since we are using energy as a proxy for the environmental load, we are interested in primary energy consumption. There is no singular definition of how primary energy should be calculated. In the case of the Norwegian energy balance, the primary energy consumption is equal to the sum of net domestic consumption, transportation and transformation losses, and energy used in production. Figure A-1 illustrates the difference between electricity consumption at the primary and final levels in Norway for 2012 and 2017, with ratios of 1.33 for 2012 and 1.34 for 2017.

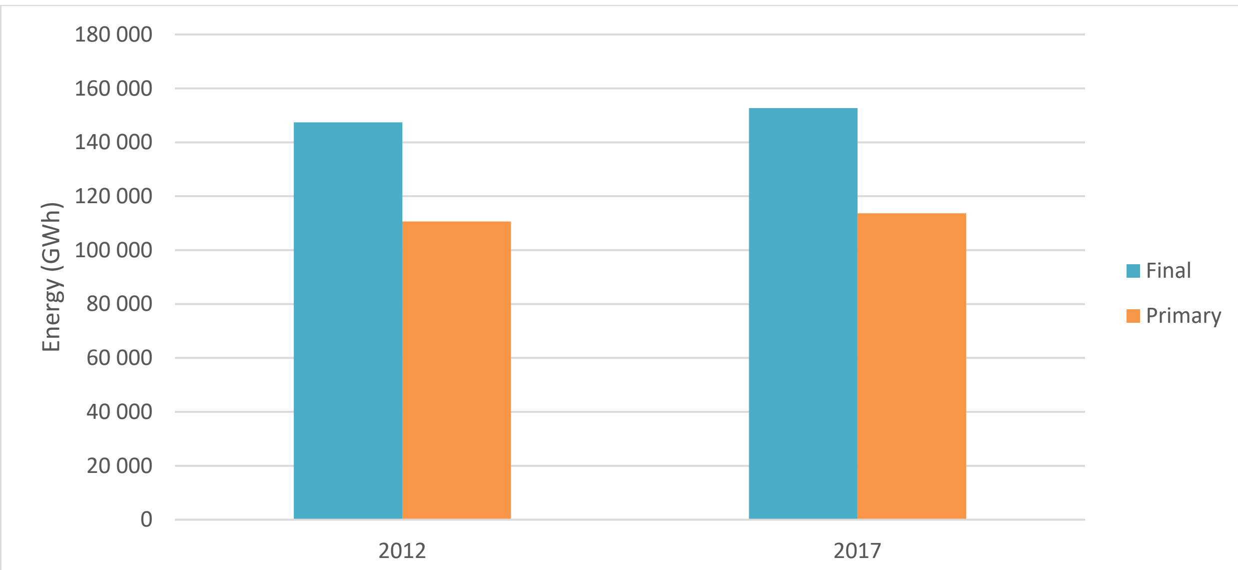

Figure A-1: Primary and final electric energy consumption in Norway, 2012 and 2017 (Statistics Norway, 2019h).

In theory, we could follow the same approach for other forms of energy, but the data is not as readily available. The numbers in the energy balance only reflect what happens in Norway, e.g. they do not include energy used in the extraction, production and transportation of petroleum or diesel to Norway from other countries. As a consequence, a better approach is to use a source that gives the conversion ratios for all forms of energy, such as the Swiss Ecoinvent database used by Hille et al. (2007). This data is proprietary, and I was unable to retrieve data from the 2015-edition. Hence, I have used the numbers from the 2005-version, as published in Hille et al. (2007, pp. 217-219). The numbers from Ecoinvent are generally higher than those we find in the Norwegian energy balance, mainly because they include a wider range of processes involved in the energy production.

Electricity consumption is always reported as energy use, e.g. MJ or kWh. To convert from end-use consumption to primary energy, we only need the ratio between the two. In this thesis, I only deal with low voltages, where the ratio is 1.52. Fuel consumption is a little different, as it is normally reported by volume in cubic metres. To calculate the primary energy use, you first calculate the weight by multiplying volume with density. The total mass is then multiplied with the factor for primary energy use. If you know the final energy use, the primary energy use is calculated by multiplying final energy with the ratio between the two, as given in Table A-1.

Fuel type	Density (kg / m^3)	Burn value (MJ per kg)	Primary energy use (MJ per kg)	Ratio (primary energy use / burn value)
Petrol (unleaded, regional storage)	0.74	42.8	57.61	1.346
Diesel (low-sulphur, at regional storage)	0.84	42.8	54.76	1.279

Table A-1: Primary energy use for petrol and diesel. Numbers from Ecoinvent (2005) as published in Hille et al. (2007).

A.2. IO-data for calculating energy use from consumption categories.

Hille et al. (2007) used data from a Dutch IO-table to produce a table of energy intensities for different consumption categories. As described in the methodology chapter, I was unable to find better data. To update the data to 2012 and 2017, I adjusted the different categories by the inflation for their respective consumption categories, as reported by Statistics Norway (2019a). This resulted in the energy intensities shown in Table A-2.

Consumption category	Energy intensity (MJ/NOK)	
	2012	**2017**
Outdoor recreation equipment	0.6193	0.6048
Bicycles	0.3851	0.3610
IT & internet	3.4572	3.3841

Table A-2: Energy intensities for consumption categories used in this thesis.

A.3. Travel expenses, daily trips

In this thesis, travel expenses are only used for daily trips related to outdoor recreation. I used the same approximations as Hille et al. (2007, p. 220), albeit adjusted for inflation, as shown in Table A-3.

Mode of transport	Expense (NOK / pkm)
Car, single occupant	5.15
Moped / MC	2.53
Public transport	1.74

Table A-3: Expenses for daily travels, 2012.

Appendix B: Results from Hille et al. (2007)

The 2001-data in this thesis were taken from Hille et al. (2007). The table below presents their results as presented in their report. In the thesis the numbers are further broken down to the component level based on the results chapter in the report.

Table B-1: The environmental load resulting from the leisure time consumption of Norwegian residents, 2002 (Hille et al., 2007, pp. 18-19)

Consumption category		Time use (million hours)	Expenditures (million NOK)	Energy use (TJ)	Energy use (MJ)	
					Per hour	Per NOK
Holiday trips by air		804	18,951	48,039	60	2.5
Culture / entertainment	Aqua parks	4	330	397	99	1.2
	Libraries	16	1,151	684	43	0.6
	Cinemas	33	1,169	689	21	0.6
	Concerts	29	1,500	651	22	0.4
	Museums	16	1,865	1,500	96	0.8
	Restaurants / cafés	300	30,536	6,783	23	0.2
	Theatre / opera	6	1,051	175	29	1.2
	Theme parks, etc.	10	776	293	29	0.4
Outdoor recreation	Trips to second homes	1,322	14,919	12,120	9	0.8
	Motorized outdoor recreation	38	3,839	4,813	127	1.3
	Traditional outdoor recreation	336	17,271	16,029	48	0.9
Hobbies	Photography	-	2,147	1,439	-	0.7
	Pets	110	1,929	1,007	9	0.5
	Music / playing instruments	51	565	328	6	0.6
Traditional home entertainment	Reading	429	9,701	7,152	17	0.7
	Traditional games	2,279	3,084	1,726	1	0.6
Modern home entertainment	Computers / internet	580	7,813	11,605	20	1.5

	TV and audio	3,195	7,683	11,605	20	1.5
	Audio-visual equipment	562	4,446	5,883	10	1.3
Visiting relatives / friends	Visiting relatives / friends	1,602	24,161	35,718	22	1.5
Sports and working out	Sports – participant	147	5,468	7,401	50	1.4
	Sports – observer	33	913	700	21	0.8
	Gyms	46	1,000	1,993	43	2.0
Organizational work	Religious organizations	61	4,336	3,205	53	0.7
	Others	111	590	789	7	1.3
Homes and gardens	Gardening	226	4,170	5,370	24	1.3
	Redecoration	37	76	14,169	156	0.8
Shopping		-	-	-	-	-
Hobbies (evening courses		21	593	696	33	1.2
Conference tourism		144	5,715	7,439	52	1.3
Total / average		**12,511**	**177,702**	**192,569**	**15**	**1,1**