

A case study regarding the carbon footprint for one day trips to different ski destinations in the Jämtland region.

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2016

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Ecotechnology and Sustainable Building Engineering

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Degree program: Ecotechnology, 180 credits

Main field of study: Environmental Science

Semester, year: VT, 2016

Abstract

Currently, World is facing global warming, which threatens especially winter tourism. Many glaciers started to melt significantly as well as winter seasons get warmer and shorter in many ski areas (Gilaberte-Búrdaloa, et al., 2014). It is a really important issue and challenge especially for ski resorts. However, in spite of ski resorts there are also millions of tourists visiting ski destinations every year. Due to that it should also be important to all those winter enthusiasts to know and reduce their own impacts on environment, if they still want to enjoy snow-based sports and natural beauty of a mountain environment. Due to that, this study chosen to focus on emissions from ski trips seeing form the perspective of the skier in one of the most famous ski region in Sweden. The carbon footprint concept was used to calculate and compare four trips to different ski destinations such as Åre, Vemdalen, Frösön and Storulvån. From each trip the following factors where considered: emissions from production of ski equipment, emissions from skier travel, from purchased electricity in the ski resort and from consumption of fuel by vehicles on the slopes. At least six transportation scenarios per destination were created to investigate possible modes of transportation and their impacts. The results showed that the total amount of carbon footprint per skier differed among the trips from 74.01 kg to 2.40 kg of CO₂-eq. per skier depends on the transportation scenario and destination. It was concluded that skier travel can be a huge source of emissions depending on the distance to chosen destination and type of the transport. However, it was found out that impact from skier travel as well as from ski equipment can be reduced by individual's choices. Moreover, it was also concluded that the fuel consumed by vehicles on the slopes had a significant impact in all ski resorts and it should become the major issue for ski resorts to find new solutions and practices, which would reduce the amount of emissions.

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List of abbreviations:

GHGs	Greenhouse Gases
LCA	Life Cycle Assessment
EPA	Environmental Protection Agency
ISO	International Organization for Standardization
PAS	Publicly Available Specification
CO ₂ -eq.	Carbon dioxide equivalent
CO ₂	Carbon dioxide
CH ₄	Methane
N ₂ O	Nitrous Oxide
HFCs	Hydrofluorocarbons
PFCS	Perfluorocarbons
SF ₆	Sulphur hexafluoride
SEK	Swedish Krona
OSD	Östersund

1. Introduction

It was investigated that there is a link between the climate change and high emissions of GHGs produced by humans in the last century (Minx, et al., 2008). Figure 1 shows that since 1956 more carbon dioxide was released to the atmosphere than the volume, which is needed to keep the climate stable.

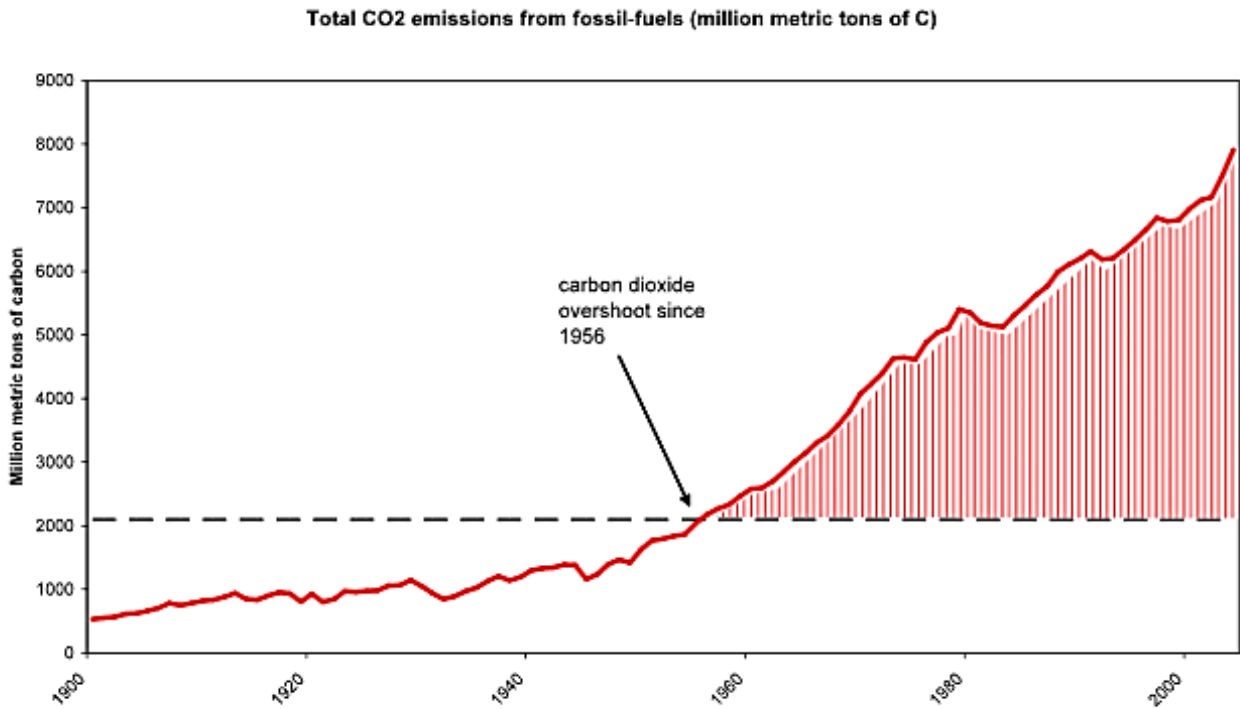


Figure 1: The overshoot of global carbon dioxide emissions (Minx, et al., 2008).

Due to many activities, from use of fossil fuels to high consumption in everyday life, humans emitted more emissions than nature was able to deal with (Senthilkannan Muthu, 2016). That created a need to find different ways to measure and assess emissions, which contribute to the global warming and then apply solutions to reduce them.

1.1 Carbon Footprint

One of the most common and leading ways to quantify emissions of GHGs is a carbon footprint. It refers to the amount of GHGs emissions produced directly or indirectly by human activities, measured in units of CO₂-eq. (Avlonas & Nassos, 2013). According to United Nations Framework Convention on Climate Change (2008), substances taken into account for the carbon footprint calculation are the main greenhouse gases such as: CO₂, CH₄, N₂O, HFCs, PFCS and SF₆. Furthermore, many tools and ways to calculate the carbon footprint concept were designed. There are models, which focus on measuring individual's carbon footprints such as online calculators provided for example by The Nature

Conservancy or EPA. There are also tools for organizations and nations to calculate their carbon footprints for example: GHG Protocol Standard for businesses and governments as well as standardizations which calculate carbon footprint from a specific product or service for example ISO 14067 or PAS 2050. The carbon footprint concept can also be used as a subset in Life Cycle Assessments, where emissions of gases are recalculated according to specific standard proportions and time horizons into CO₂-eq.. Moreover, it is important to mention that a carbon footprint can also be really often mistaken with an ecological footprint. An ecological footprint refers to measurements, which defines amount of land needed for producing and disposal of produced goods and a carbon footprint can only be used as a subset of those measurements (Senthilkannan Muthu, 2016).

1.2 Winter tourism

Tourism is one of the fastest growing economic sectors in the World (World Tourism Organization UNWTO, 2015). However, it is also really sensitive to climate conditions, as climate effects when, why and where tourists travel (Hamilton & Lau, 2004). The climate change is nowadays an important issue and a challenge to consider for tourism industry. Due to global warming especially snow-based tourism is threatened. Temperature anomalies cause glaciers melting as well as influence winter seasons, which get warmer and shorter in many ski areas (Gilaberte-Búrdaloa, et al., 2014). Through that, ski resorts are forced to put more money or find a new ways to maintain snow and still attract tourists, who want to enjoy snow sports and experience natural beauty of a mountain environment. According to the Green Resort Guide, which is a part of Respect the Mountain campaign, there are already many ski resorts implementing solutions to reduce their impacts and developing their way towards sustainability (Ski Club of Great Britain, 2012). However, in spite of ski resorts, which try to improve their operation, there are also tourists, whose choices contribute to the climate change. It is important for all kinds of winter enthusiasts to know what are the current problems and how their ski trips can contribute to climate change as well as what they can change to reduce their impacts. For example, studies from 2007 carried out by the environmental ski charity Mountain Riders, and French government agency ADEME estimated that 73% of emissions from typical ski resort comes from tourists choice of transportation to the ski resorts (Snowcarbon, 2013).

1.3 Skiing in Jämtland region

Sweden is a Nordic country with a lot of ski areas, which millions of tourists visit every year (Svenska Liftanläggningars Organisation, 2015). One of the most famous winter region is Jämtland county. It is situated in the central part of Sweden close to Norwegian border. Due to a climate with low temperatures, winter season can last quite long here usually from November till May (Skistar AB, n.d.). Due to that it is possible to find there many great ski resorts really big once or smaller once, which both providing a great ski experience for many people. Moreover, within its landscape and beautiful nature it is also well known place for ski touring trips, where a skier climbs up the mountain on his own and then ski it down. Due to all those skiing opportunities, which attract people to visit or even stay for a longer time

period in this region, it becomes interesting to measure the carbon footprint from the different ski trips performed within the Jämtland county. Through that, the amount of main emissions factors can be discovered as well as possible solutions to reduce individual's impact on environment can be found.

2. Goal

This study aims to calculate emissions from a one day ski trip from the perspective of the skier. It wants to recognize the activities with the greatest contribution by using the carbon footprint concept as a guide. It wants to show skiers the importance of climate change and their own impacts. It could be relevant for a further research within emissions and energy use in ski resorts as well as management of mountains. It can also help to build more sustainable future and can be compared with similar projects in other ski regions to understand the differences within their operations and create new solutions with less emissions. The case study was chosen to take a closer look on ski opportunities and their environmental impacts at Jämtland region.

Research questions:

1. What is the carbon footprint from a one day ski trip to Åre/Vemdalen/Frösön/Storulvån performed by an individual from Östersund?
2. Which factor contributes the most to the carbon footprint? Does it differ among trips to different destinations?
3. How does the carbon footprint change according to different transportation scenarios?

3. Method

Due to many too complex and not enough relevant standardization to calculate carbon dioxide from an activity such as one day skiing trip, this study chosen to not follow one specific method. It tries to combine parts from different available tools and standardization. Furthermore, emissions where quantified through gathering the data from companies and organization, which provided the results of real measurements. Estimations based on emission factors were used to provide the data for calculation.

3.1 System boundaries

According to Senthilkannan Muthu, (2016), system boundaries describes a targeted region and considers activities within the boundary. This study aims at calculating one day of ski trip. There are necessary things, which an individual needs, to go skiing such as equipment (proper clothes and the pair of skis) and transportation to the spot, where skiing is possible (a hill/mountain with sufficient layer of snow and gradient). Those are also the main things, which an individual can have influence on or even own. For example: a person can choose what kind of equipment he buys and what mode of transportation he uses.

Furthermore, a skier can also make a decision where to go skiing, to which resort or ski area. If he chooses a ski resort then he travels to the specific place, which is prepared and controlled by the owner of the ski resort. The lift system and slopes are prepared to provide satisfying skiing conditions for skiers. However, many operations within ski resort use energy and have an impact on environment. According to The National Ski Areas Association , (2015), which used the GHG Protocol Standard in its studies, three scopes of direct and indirect factors from ski resorts contribute to GHG (Figure2).

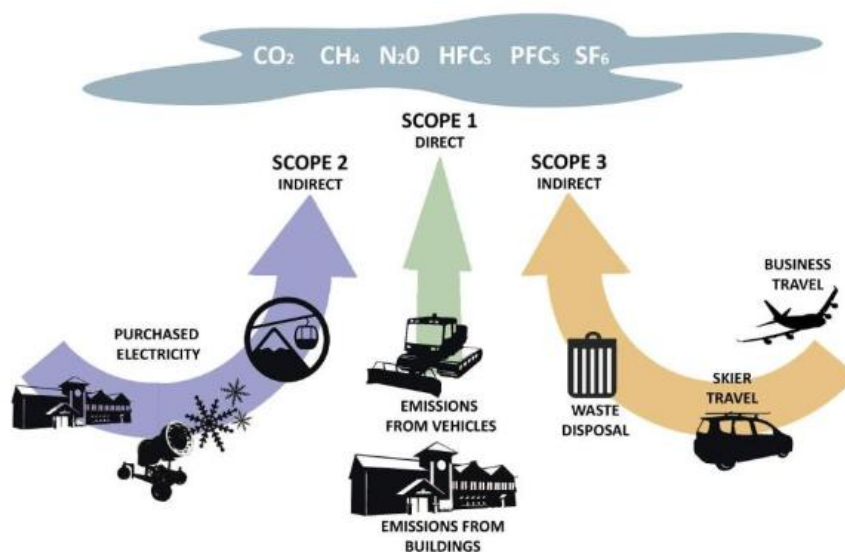


Figure 2: Direct and indirect factors from a ski resort, which contribute to GHG emissions.

Figure 2 shows:

- Direct Scope 1: emissions from vehicles (fuel), emissions from buildings
- Indirect Scope 2: Purchased electricity for snowmaking, buildings and lifts
- Indirect Scope 3: Waste disposal, skier travel, business travel

This study aims to calculate the carbon footprint just for one day of skiing, due to that the boundaries of this study includes following factors: the amount of purchased electricity to operate ski resort, emissions from vehicles, skier travel as well as the ski equipment. Those categories were chosen because they provide basic conditions needed for one day of skiing in chosen destinations. The rest of factors from ski resorts such as: emissions from buildings, waste disposal and business travel were not taken into account in this report.

Considering all things needed to go for one day skiing trip in Jämtland following emissions factors were investigated for each trip (Table 1).

	Åre	Vemdalen	Frösön	Storulvån
Emissions from the ski equipment	✓	✓	✓	✓
Emissions from the transportation	✓	✓	✓	✓
Emissions from the amount of purchased electricity by ski resort	✓	✓	✓	✗
Emissions from the vehicles on the slopes	✓	✓	✓	✗

Table 1: Factors taken into consideration for one day skiing trips within Jämtland region. Two factors were not considered during the trip to Storulvån because it is a ski touring destination where there is no ski resort, so neither lifts nor prepared slopes (marked with (✗)).

3.2 Data collection

3.2.1 Analyzed ski destinations

One of the most famous and biggest Swedish ski resort is called Åre. It is a well-known place, which host many world cup competitions and other sport events every season (Skistar AB, n.d.). It is situated in Jämtland county, close to Norwegian border. Furthermore, there is another big ski destination in Jämtland region called Vemdalen, which offers all-around skiing with thrilling vertical drops (Skistar AB, n.d.). Both of these ski resorts are owned by a company called SkiStar, which is the leading operator of European alpine destinations. Nevertheless there are many more ski areas, which Jämtland region offers. One of the most beautiful places to climb a mountain peak on your own and then ski it down is Storulvån. With a lot of different trails it creates a perfect place for ski touring trips (Mountainsports ,

2015). All those destinations are well-known and often visited by people from Östersund – the capital of Jämtland region. Östersund is a winter city, which attracts a lot of people to stay and explore the region within its ski opportunities. However, even if there are a lot of destinations to make ski travels to, Östersund offers a ski experience in the city itself. A small ski resort is situated on the island called Frösön, where two slopes on each side of the hill can be found - Gustavsbergsbacken/Ladangen (Selax AB, 2016).

To get the most relevant and trustful data about analyzed ski resorts the ski resorts' official websites as well as personal communication with the board of Gustavsbergsbacken, Ski Star and Jämtkraft were used to collect a following data (Table 2).

	Åre	Vemdalen	Gustavsbergsbacken & Ladängen
One way distance from Östersund (km)	104	114	5.9
Typical length of the season	November - May	November - April	December - April
Amount of lifts	42	35	3
Amount of slopes	89	58	4
Approximated total length of slopes (km)	101	52	1.38
Skier days in 2015/2016 season	978000	602000	6894
Cost of 1day ski pass for adult (SEK)	425	370	120
Electricity purchased during the season 2015/2016 (kWh)	10914478 (period: 2015-11-01 – 2016-05-01)	No data 5619336	608 988 (period: 2015-12 – 2016-03-31)
Fuel used for vehicles on the slopes during the season 2015/2016 (l)	No data 585508 - diesel 46841 - petrol	No data 301450 - diesel 24116 -petrol	8000 - diesel 640 - petrol

Table 2: Basic information about ski resorts in Jämtland region (Skistar AB, n.d.), (Selax AB, 2016).

The table used comment "No data" when the information were not found. Under "No data" the recalculated results were highlighted by red color.

Due to lack of data the amount of electricity purchased in Vemdalen resort was recalculated through the proportion with Åre resort considering length of the slopes. Moreover, the data about the consumption of fuel for vehicles on the slopes during the season was collected only for slopes in Frösön. Due to that the amount of fuel liters used in slope vehicles such as grooming machines and snowmobiles, in Åre and Vemdalen was recalculated through proportion to Frösön considering length of the slopes (Table 2).

3.2.2 Ski equipment

Emissions from ski equipment were divided into two section: emissions from production of one pair of skis and production of ski clothes. The study considered that ski equipment is owned by a skier. The existing LCA studies on skis (Luthe, et al., 2013) and ski clothes (Persson, 2015) were used to estimate potential emissions from those factors.

3.2.3 Transportation scenarios

There are many variants of travelling to chosen destinations. There are also variety of transportation modes, which each of them has different fuel consumption and energy use. To investigate this part as relevant as possible twenty seven potential scenarios were created with a starting point in Östersund.

Road	Type of transportation	Amount of passengers
OSD- Åre	Petrol car	1
OSD- Åre	Petrol car	4
OSD- Åre	Diesel car	1
OSD- Åre	Diesel car	4
OSD- Åre	Electric car	1
OSD- Åre	Electric car	4
OSD- Åre	Bus	Full bus
OSD- Åre	Train	Full train
OSD- Vemdalen	Petrol car	1
OSD- Vemdalen	Petrol car	4
OSD- Vemdalen	Diesel car	1
OSD- Vemdalen	Diesel car	4
OSD- Vemdalen	Electric car	1
OSD- Vemdalen	Electric car	4
OSD- Vemdalen	Bus	Full bus
OSD- Frösön	Petrol car	1
OSD- Frösön	Petrol car	4
OSD- Frösön	Diesel car	1
OSD- Frösön	Diesel car	4
OSD- Frösön	Electric car	1
OSD- Frösön	Electric car	4
OSD- Frösön	Bus	Full bus
OSD- Storulvån	Petrol car	1
OSD- Storulvån	Petrol car	4
OSD- Storulvån	Diesel car	1
OSD- Storulvån	Diesel car	4
OSD- Storulvån	Electric car	1
OSD- Storulvån	Electric car	4

Table 3: Transportation scenarios to each investigated destination.

The train alternative was only possible to take to Åre. The bus alternative was possible to take to Åre, Vemdalen and Frösön.

3.3 Calculation

The following section describes calculation of emissions from each investigated factor for one day skiing trip in the expression of the carbon footprint presented in the CO₂-eq. per one skier.

3.3.1 Ski equipment

The amount of CO₂-eq. estimated by the LCA research on production of skis from Luthe, et al., (2013) was recalculated for the pair of skis considering results from a conventional ski. Furthermore, the amount of CO₂-eq. from the set of ski clothes estimated by the study on the Rent A-Plug company were taken into consideration (Persson, 2015). The amount of emissions estimated by studies from the pair of skis as well as the general set of ski clothes were divided by 30 days of usage to get a reasonable amount of emissions per skier.

3.3.2 Transportation

To calculate scenarios, which uses a car, the same model of the car was chosen for each scenario to make the study the most comparable as possible. According to statistics Volvo and Volkswagen were two brands, which had the biggest amount of sold car units in 2014 in Sweden (Statista, 2016). From first three top models the Volkswagen Golf was chosen for investigation because the data about the model could be find in each version as petrol, diesel and electric car. The efficiency and specification of each car version are enclosed in Appendix 1. To make the study more related to the real life the short distance trip to Frösön was calculated through assessment of the fuel efficiency during the drive in the city. The fuel efficiency for the long distance trips to Åre, Vemdalen and Storulvån through the assessment of a highway mode according to U.S. Department of Energy & U.S. Environmental Protection Agency, n.d.. Furthermore, the amount of liters used during the transportation for both ways was calculated. The specific emissions rate was chosen according to U.S. Energy Information Administration, (2016);

- Petrol: 2.35 kg CO₂/l
- Diesel: 2.68 kg CO₂/l

Emissions rate for electric car was calculated by using the average emissions rate for electricity in Sweden 0.03 kg CO₂/kWh (Kellberg, 2012). According to Kellberg, (2012), the Swedish electricity production consists largely of hydropower and nuclear power, which emits 20 grams of CO₂ emissions per 1 kWh in Sweden. However, during the dry years it can reach 40 grams of CO₂ emissions per 1 kWh.

To calculate scenarios, which uses available means of public transport to chosen destinations, online calculator was used (Network for Transport Measures, n.d.). The amount of CO₂-eq. was taken into account considering a city bus option and a passenger train type: a conventional IC train.

3.3.3 Use of electricity and fuel in ski resorts

To calculate emissions per skier the total amount of purchased electricity from season 2015/2016 was divided by amount of skier days in season 2015/2016. Skier days is a common unit to measure the number of skiers in any one particular ski area (Glosbe, 2015). It relates to days of skiing purchased during particular season.

Furthermore, the emission rate from electricity was calculated by using the average emissions rate for electricity in Sweden. For specific rate see part 3.3.2 Transportation.

The standard emissions rate for diesel and petrol was applied from U.S. Energy Information Administration, (2016). For specific rate see part 3.3.2 Transportation. The emission of CO₂ from both type of fuels were summed together and divided by skier days according the destination.

3.4 Data limitations

This report focused on emissions seen from the perspective of the skier. Due to that the whole LCA studies were applied for the ski equipment because of the assumption that ski equipment belongs to a skier. In transportation scenarios due to big variety of possible modes of transport as well as the possibility of making a choice, which specific mode can be used, this study included just the usage phase of the products such as cars, buses or trains. Furthermore, this report also chosen to taken into consideration purchased electricity in a ski resort and fuel used by vehicles on the slopes. This study does not consider LCA of lifts, grooming machines or snow mobiles. Moreover, other factors considered by The National Ski Areas Association, (2015) within ski resorts such as emissions from buildings, waste disposal and business trips (Figure2) were not included in this report due to not being enough relevant to the investigated target of one day ski trip.

Due to problems with providing the specific data by Ski Star about Åre and Vemdalen resorts considering total capacity of lifts and slope lighting as well as amount of fun guns and cannons for snow making, snow making hour per year etc., only the total amount of electricity purchased in the season 2015/2016 was taken into account. Due to that, the amount of electricity is consider to be a total amount needed for all ski resort activities considering operation of lifts, lighting of the slopes, snow making and lifts buildings. Moreover, purchased electricity in Vemdalen was estimated through proportion to electricity used in Are and fuel used for vehicles on the slopes in Åre and Vemdalen resorts were estimated trough proportion to fuel used in Frösön.

4. Results

The figures under shows the total emissions of CO₂-eq. per skier for each transportation scenario.

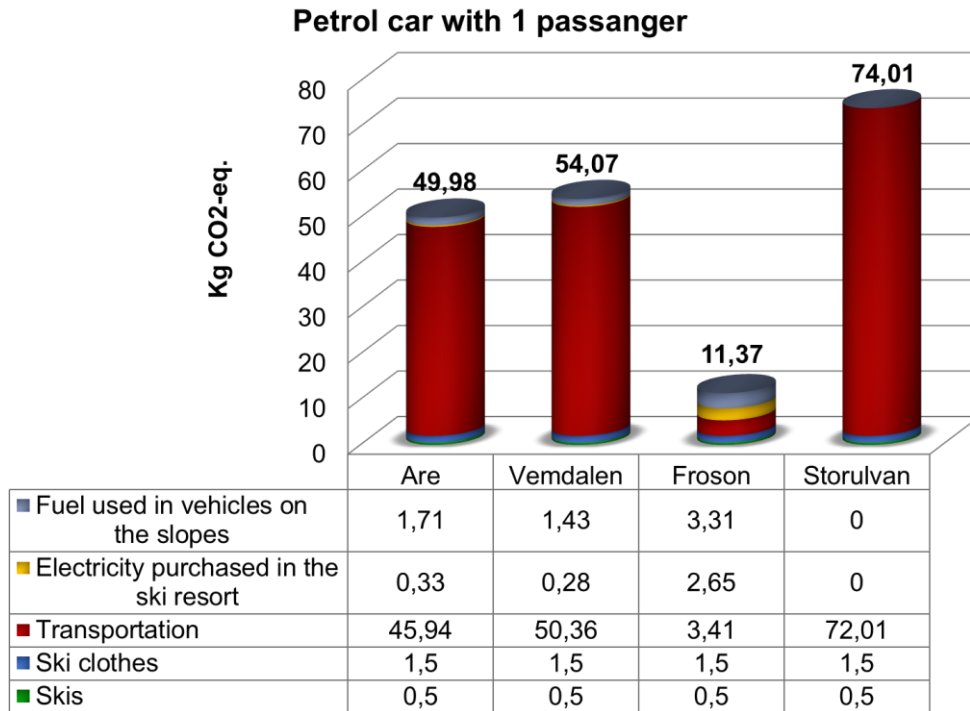


Figure 3: The total amount of CO₂-eq. for each trip per skier using a petrol car with one passenger for transportation.

In this scenario the main contributing factor for all the trips is transportation to the ski area. The biggest amount of CO₂-eq. from all of scenarios and trips is produced during drive to Storulvån by using a petrol car with 1 passenger (Figure 3). The amount of emissions from transportation in proportion to other factors is 97% for this trip.

Petrol car with 4 passangers

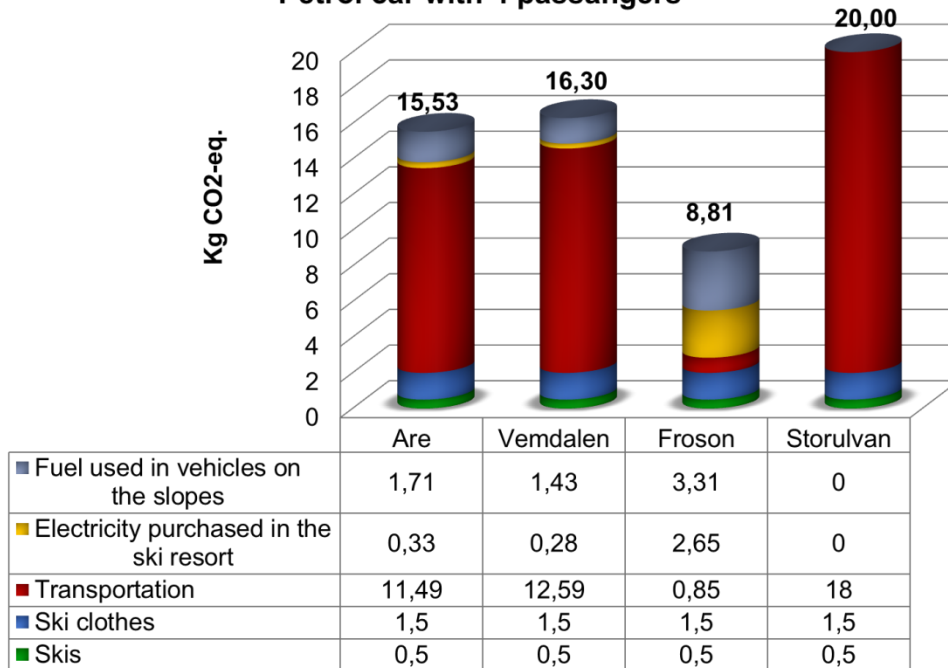


Figure 4: The total amount of CO₂-eq. for each trip per skier using a petrol car with four passenger for transportation.

Diesel car with 1 passanger

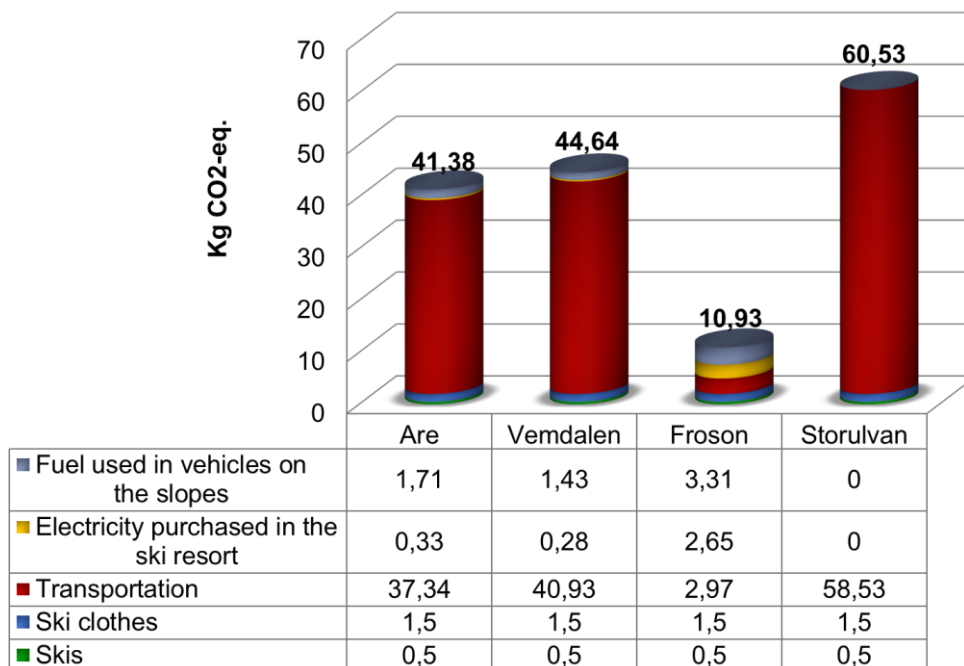


Figure 5: The total amount of CO₂-eq. for each trip per skier using a diesel car with one passenger for transportation.

Diesel car with 4 passangers

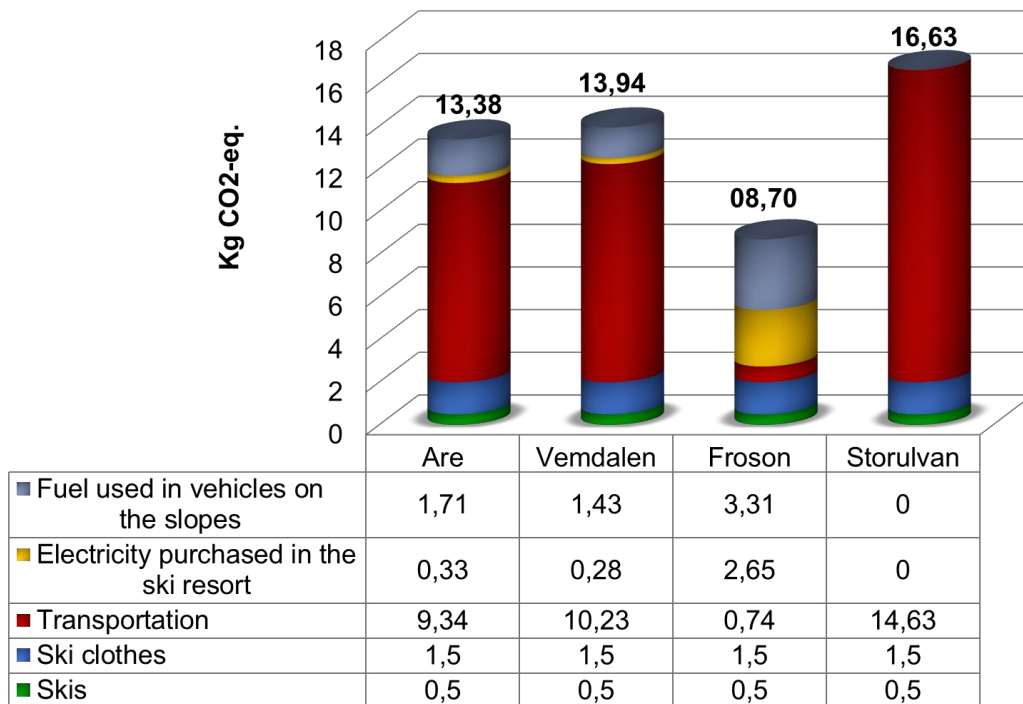


Figure 4: The total amount of CO₂-eq. for each trip per skier using a diesel car with four passenger for transportation.

In all the scenarios above with petrol or diesel car the skier transportation has the main and significant impact to long distance destinations such as Åre, Vemalen and Storulvån (Figure 3; 4; 5; 6). In the short distance scenarios to Frösön, the main contributor in the scenario with a petrol car with one passenger is also transportation (Figure 3). However, in all the other scenarios, fuel burned while using vehicles on the slopes is the main factor during Frösön trip (Figure 4; 5; 6). The electricity used in the ski resorts such as Åre and Vemdalen has the lowest impact from all the analyzed factors. However, the impact from purchased electricity for Frösön trip is quite significant.

Electric car with 1 passenger

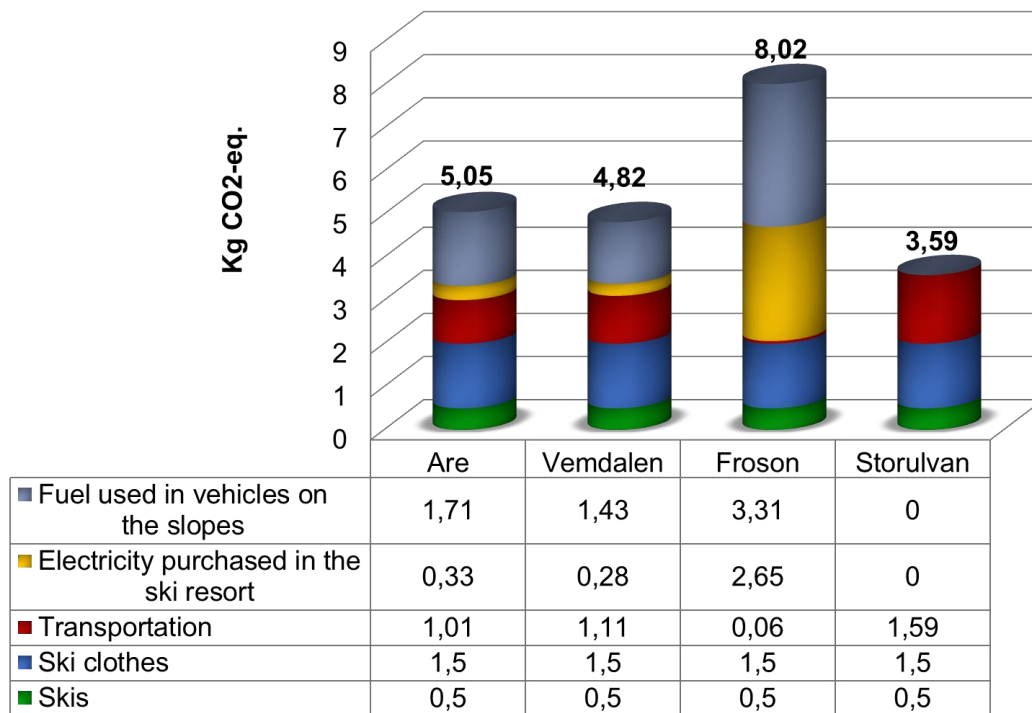


Figure 5: The total amount of CO₂-eq. for each trip per skier using an electric car with one passenger for transportation.

Considering scenario with an electrical car with 1 passenger, it is seen that the biggest impact has the Frösön trip even though it is the closest destination to go. The main contributors are fuel used in vehicles on the slopes and purchased electricity at the ski resort (Figure 7). In Åre and Vemdalen main emissions factors are fuel used in vehicles on the slopes and ski clothes (Figure 7). The trip to Storulvån by an electric car shows that the emission from transportation are almost the same as from ski clothes (Figure 7).

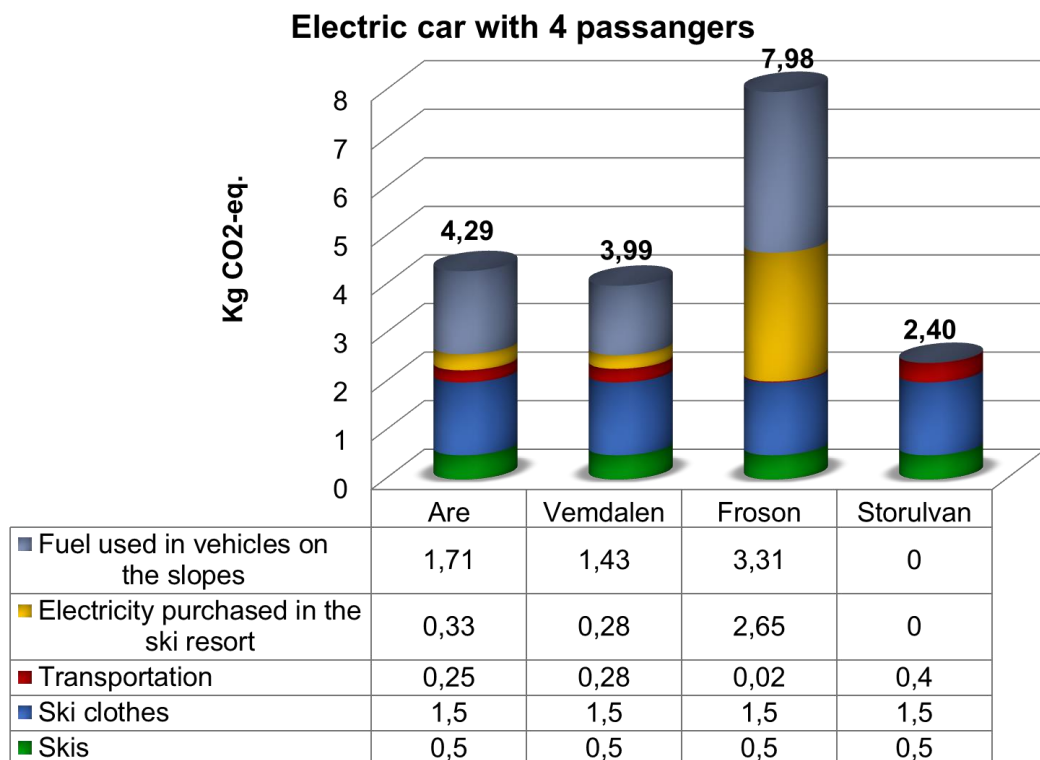


Figure 6: The total amount of CO₂-eq. for each trip per skier using an electric car with four passenger for transportation

The lowest amount of CO₂-eq. from all of the scenarios is produced during trip to Storulvån by an electric car with 4 passengers (Figure 8). Even the emissions from skis is slightly higher than emissions from transportation part.

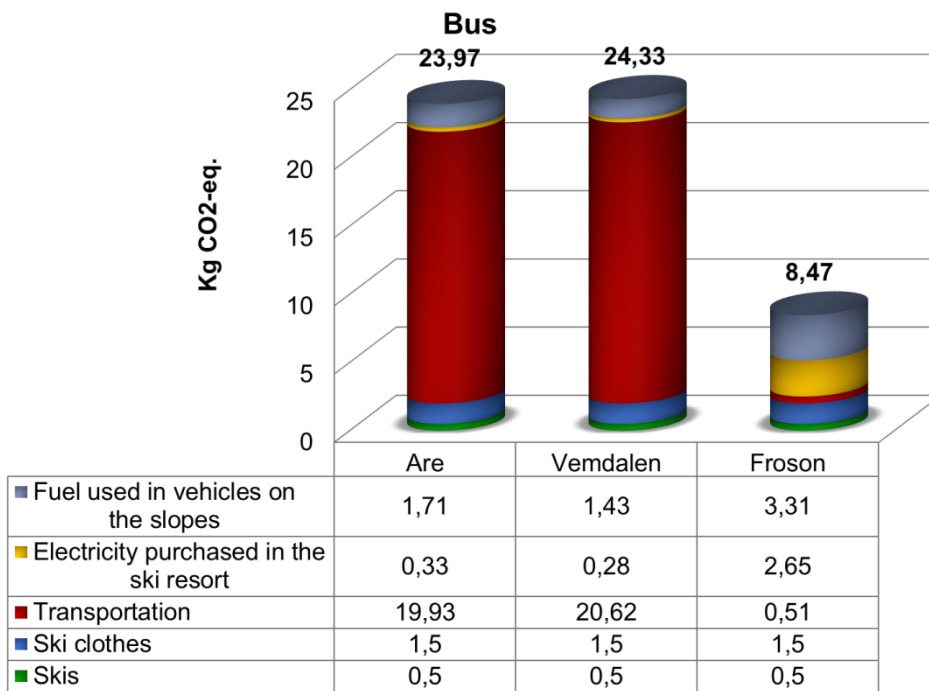


Figure 7: The total amount of CO₂-eq. per skier for trips to Åre, Vemdalen and Frösön using a bus for transportation.

The bus scenario shows that transportation contributes quite a lot to long distance destinations such as Åre and Vemdalen (Figure 9).

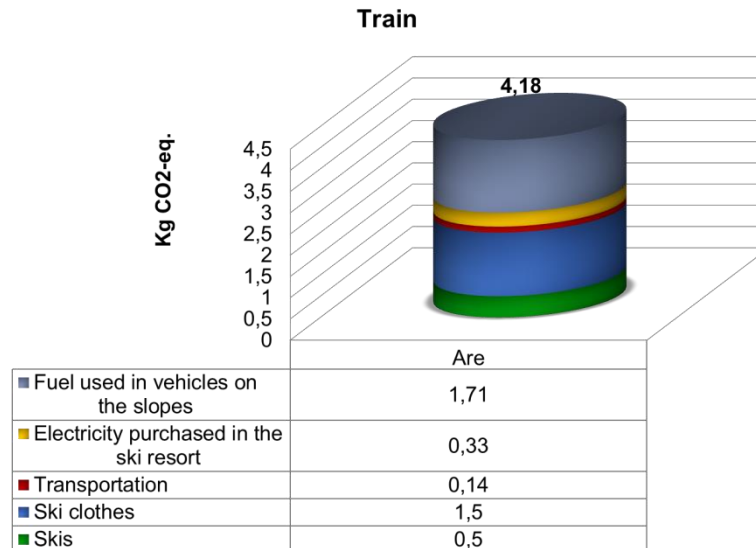


Figure 8: The total amount of CO₂-eq. per skier for the trip to Åre by train.

Considering a scenario with using a train to Åre the main contributors are fuel used in vehicles on the slope as well as ski clothes (Figure 11). Moreover, it can be noticed that the impact from using an electric car with 4 passengers to Åre can be comparable with using a train (Figure 9).

In all scenarios for Åre and Vemdalen it is noticed that the purchased electricity has always a low impact. However, in Frösön it is a big part of emissions.

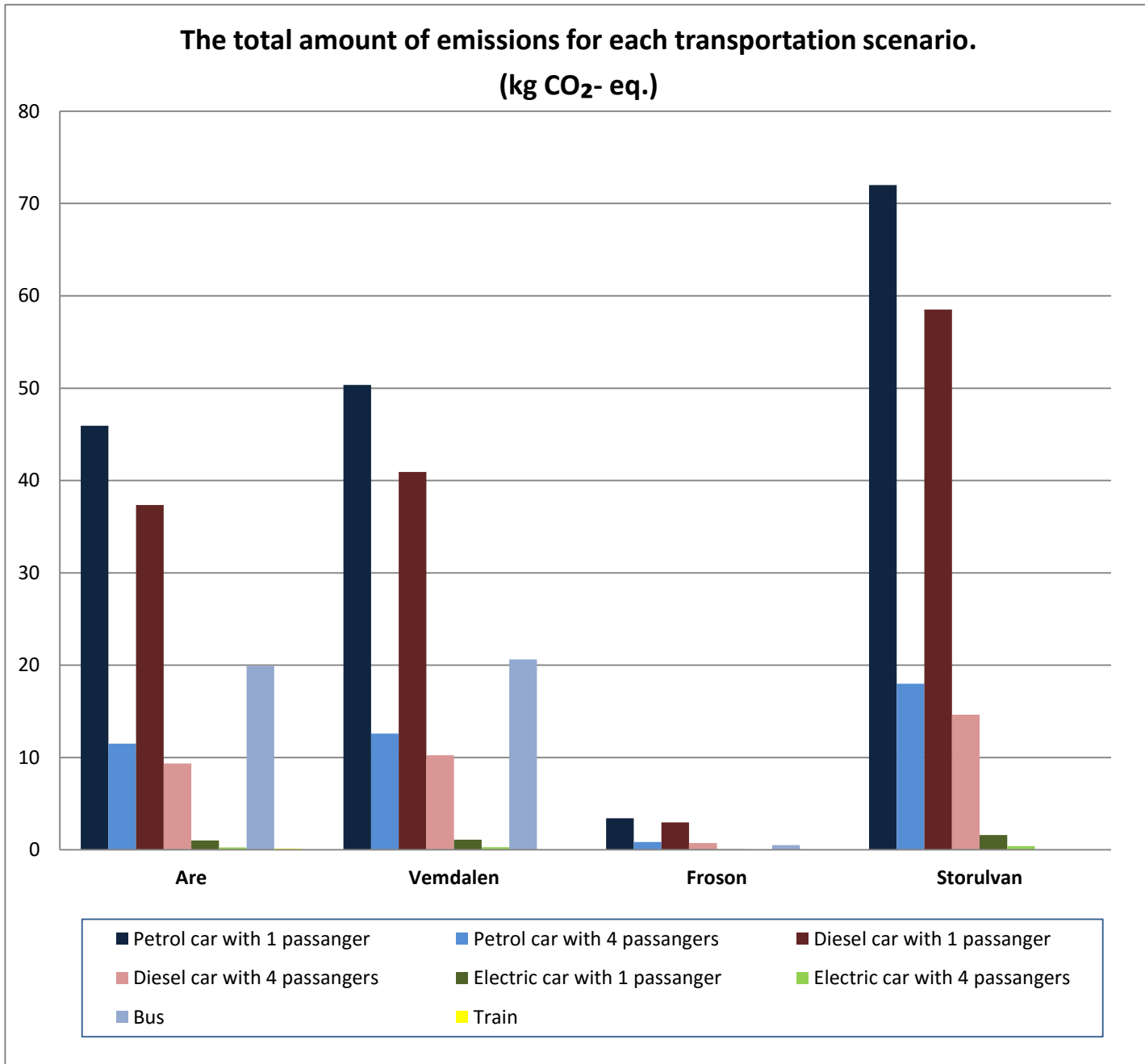


Figure 9: Comparison of emissions from different transportation scenarios to each investigating destination.

Comparing different modes of transportation in Jämtland, the biggest emissions to each destination come from using of a petrol as well as a diesel car with 1 passanger. Electric cars as well as train emit significantly less emissions per person. Furthermore the emissions from use of a bus are higher than use of a petrol or diesel car with 4 passangers to Åre and Vemdalen (Figure 4; 6).

5. Discussion

The factor, which definitely contributes much in the majority of scenarios is a skier transportation. It has a significant impact until it is switched for using electric car or train. It can be concluded that it relates to a distance because the biggest emissions are especially from the long distance travels to Åre, Vemdalen and Storulvån.

Furthermore, the fuel used on the slopes is one of the main contributors in Frösön resort as well as in trips to Åre and Vemdalen when the electric car scenarios are used. This is the one of the major issue at the ski resorts within which the new solutions need to be developed to reduce the impact.

Through considering two main contribution such as transportation as well as fuel consumed in the vehicles on the slopes, it can be noticed that the main problem lies in emissions from burning of fossil fuel such as petrol and diesel by the skier travel as well as by vehicles on the slopes such as grooming machines and snowmobiles.

Nevertheless, it can also be noticed that the production of ski clothes have a quite big impact according to their LCA (Persson, 2015). However, it has to be considered that the 30 days of usage for ski equipment was chosen, so depends on personal habits the usage phase could be longer or shorter and at the same time impact could be higher or lower.

Moreover, the results shows that purchased electricity in Åre and Vemdalen ski resorts have the lowest impact from all the investigating factors. However, in Frösön it is still one of the greatest contributor. The difference could be explained by weather conditions in this particular season 2015/16, so the resort in Frösön had to produce a lot of artificial snow. However, there is also a huge difference between amounts of skiers visiting those resorts, which could cause bigger contribution per individual from small resort such as Frösön.

In addition, it is needed to consider that this study made an investigation only for one day long ski trip. The amount of carbon footprint and contribution factors can change depends on the length of the skiing trip.

Furthermore, emissions from skier travels and ski equipment depends a lot on skier decisions. Individual can choose where to go and how, what kind of ski equipment purchase and its usage length. It is important to not be unconcerned about the climate change especially when an individual is a skier and his main destinations are currently under the threat. However, there are factors such as ski trip costs or experience itself of the specific mountains, which can have bigger influence on the skier decisions.

Nevertheless, applying easy solutions such as traveling with more people while using a car, going to the ski destination by public transport or traveling more often to closer destinations, could make a huge difference. In addition, to decrease carbon footprint from ski equipment it is important to care about own ski equipment because it makes it possible to use it longer as well as to support companies which using sustainable practices by purchasing products from them. Through those little changes in skiers' behaviors the carbon footprint from ski trips could drop significantly.

6. Conclusion

The total amount of carbon footprint per skier differs among the trips from 74.01 kg to 2.40 kg of CO₂-eq. depends on the transportation scenario and destination. It can be concluded that skier travel can be a huge source of emissions depending on the distance and type of the transport. In scenarios with cars and buses using fossil fuels to long distance destinations such as Åre, Vemdalen and Storulvån transportation has the biggest impact. However, in scenarios to short distance destination such as Frösön fuel consumed in vehicles on the slopes is rather the main contributor. When the scenario with an electric car with 4 passengers is investigated the impact from transportation part drops significantly and the main contributor in all ski resorts is fuel used in vehicles on the slopes. In the same scenario it can also be noticed that during the ski touring trip to Storulvån the transportation drops greatly and the ski clothes contribute much more than the skier travel. Nevertheless, it is concluded that impacts from transportation and ski clothes can be reduced by individual's choices. However, the fuel consumption by vehicles on the slopes should be the major focus for the ski resorts to find new solutions to reduce the environmental impact.

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Appendix 1

Car model	Efficiency in the city	Efficiency on the highway
2014 Volkswagen Golf diesel 2.0 L, 4 cyl, Auto(AM-S6), Turbo	9,4 l/100km	6,7 l/100km
2014 Volkswagen Golf patrol 2.5 L, 5 cyl, Automatic (S6),	12,3 l/100km	9,4 l/100km
2015 Volkswagen e-Golf Automatic (A1) range:133km	19,53 kWh/100km	16,27 kWh/100km

Table 4: Fuel efficiency of the investigated models according to city and highway modes. (U.S. Department of Energy & U.S. Environmental Protection Agency, n.d.)

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