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The Big Car Dilemma

Exploring Consumer Attitudes Toward Vehicle Size and the
Barriers to Downsizing

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Abstract

The increasing size and mass of passenger cars threatens to reduce the climate benefits that electrification bring. This thesis investigates consumers' preferences to passenger car sizes, barriers to vehicle downsizing, and demographic, social, and policy-related factors influencing car size purchasing choices in Sweden. A mixed-method approach was employed, including a literature review, statistical analysis using national vehicle registry data, interviews with experts, and a specific energy use model. The results show that while preferences for larger cars are increasing for all types of cars (i.e., gasoline, diesel and electric), they are influenced by several factors such as income, place of residence, household size, housing type, and gender. However, the difference in mean mass in running order has decreased over time for most of the factors, indicating an underlying general trend towards larger cars for all consumers since there is a general trend towards larger cars. The factors where the differences have either increased or remained are the place of residence and housing type. Larger vehicles lead to increased specific energy use and increased energy use during production, increased material demand, and increased life-cycle emissions, even for electric cars. There are both psychological and functional barriers to downsizing, including perceptions of safety, comfort, lifestyle needs, and status. The results of the expert interviews pointed to that if downsizing is desired, some type of political intervention is needed. Targeted incentives to promote smaller, more sustainable vehicles are needed, such as feebates or weight-based taxation. This study aims to contribute to a better understanding of the trend in consumers' preferences towards larger and heavier passenger cars, and may help in developing future strategies for encouraging more sustainable choices.

Keywords: Downsizing, consumer preferences, vehicle mass, vehicle size, electric vehicles

Det stora bil-dilemmat

En studie om konsumenters attityder till bilstorlek och hinder för att välja mindre fordon

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Sammanfattning

Personbilars ökande storlek och vikt hotar att minska de klimatfördelar som elektrifieringen medför. Denna uppsats undersöker konsumenters preferenser för personbilars storlek, hinder för att välja mindre fordon samt demografiska, sociala och politiska faktorer som påverkar val av bilstorlek i Sverige. Flera metoder användes, inklusive en litteraturöversikt, statistisk analys av nationella fordonsregisterdata, intervjuer med experter och en modell för specifik energianvändning. Resultaten visar att preferenser för större bilar ökar för alla typer av bilar (dvs. bensin, diesel och el), men påverkas av flera faktorer såsom inkomst, bostadsort, hushållsstorlek, boendetyper och kön. Skillnaden i genomsnittlig tjänstevikt har dock minskat över tid för de flesta faktorer, vilket tyder på en underliggande generell trend mot större bilar för alla konsumenter då det finns en generell trend mot större bilar. De faktorer där skillnaderna antingen har ökat eller varit oförändrade är bostadsort och boendetyper. Större fordon leder till ökad specifik energianvändning och ökad energianvändning vid produktion, ökat materielbehov samt ökade livscykelutsläpp, även för elbilar. Det finns både psykologiska och funktionella hinder för att välja mindre fordon, inklusive uppfattningar om säkerhet, komfort, livsstilsbehov och status. Resultaten från expertintervjuerna pekar på att om en minskning i fordonsstorlek önskas, krävs någon form av politiskt ingripande. Riktade incitament för att främja mindre och mer hållbara fordon behövs, såsom ett bonus malus-system eller en viktbaserad beskattning. Denna studie syftar till att bidra till en bättre förståelse av trender i konsumenternas preferenser mot större och tyngre personbilar, och kan bidra till utvecklingen av framtida strategier för att uppmuntra mer hållbara val.

Nyckelord: Storleksminskning, konsumentpreferenser, fordonsmassa, fordonsstorlek, elbilar

Nomenclature

EV - Electric vehicle

EU – European Union

BEV - Battery electric vehicle

ICE - Internal combustion engine

ICEV - Internal combustion engine vehicle

SUV - Sport utility vehicle

CO₂ - Carbon dioxide

VED - Vehicle excise duty

HSS - High-strength steel

LCA - Life cycle assessment

WLTC - Worldwide Harmonized Light Vehicles Test Cycle

WLTP - Worldwide Harmonized Light Vehicles Test Procedure

MPG – Miles per gallon

USA – United States of America

GDP – Gross domestic product

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1 Introduction

The use of passenger cars and vans is widespread across the whole planet. The use of these vehicles leads to material consumption and carbon dioxide emissions, resulting in consequences such as global warming. Passenger cars and vans accounted for 25% of global oil use and around 10% of global greenhouse gas emissions in the year 2023 (IEA, 2025a). To reduce these impacts, the transport sector is currently transitioning towards electrification, with battery electric vehicles (BEVs) playing an important role in reducing greenhouse gas emissions. The EU regulation of CO₂ emissions from passenger cars is expected to lead to a gradual phase-out of internal combustion engine vehicles within Europe (European Commission, 2024). In 2024, BEVs reached a sales share of more than 20%, with the Chinese market accounting for almost half of all global sales. The 11 million cars sold in China in 2024 were more than all global sales combined in 2022 (IEA, 2025b). These trends point to a peak in the demand for car fossil fuels and, thus, a peak in related CO₂ emissions.

However, an emerging trend may hinder this development. The sales of SUVs have increased to 48% of global sales of new passenger cars in 2023 compared to less than 20% back in 2010 (IEA, 2024). The consumption of larger and less energy-efficient vehicles may undermine the potential gains from electrifying the car fleet (Brand, 2024). Globally, a trend towards larger and heavier passenger cars has been observed, leading to an increase in the specific energy use of BEVs and a need for larger batteries (Brand, 2024). With larger vehicles, the material demand and energy demand will increase in vehicle manufacturing, leading to higher associated emissions throughout the vehicle lifecycle. ICCT (2024) presents the vehicle mass in running order by country in their yearly report on European vehicle market statistics. In this report, it becomes clear that it is not just for Sweden that a trend towards heavier cars can be observed, all analyzed countries show similar trends, especially in the later parts of the 2010s and during the 2020s. The countries with, on average, the heaviest cars are all Nordic countries. The top 5 include Norway with a mean mass of 2,019 kg, Iceland with a mean mass of 1,859 kg, Sweden with a mean mass of 1,836 kg, Finland with a mean mass of 1,750 kg, and Denmark with a mean mass of 1,705 kg.

New cars in Europe are also becoming wider. The growth in width is around 1 cm every 2 years, on average (T&E, 2024). It has escalated to such an extent that out of the top 100 of sold car models, 52 of them are now too big to fit into smaller parking spaces. In 2023, the average car width was around 180.3 cm, compared to 177.8 cm in 2018, which indicates that

the trend may be continuing, and, according to current legislation, cars are allowed to be as wide as large trucks with a width of 255 cm.

In an article by Ellingsen et al. (2016), the total greenhouse gas emissions for BEVs are compared depending on the size of the vehicle. They found that when comparing lifecycle emissions, the production of BEVs was more environmentally intense than that of ICEVs. But the usage of BEVs has a lower environmental footprint than ICEVs. For BEVs to become less polluting, they needed to be driven a certain distance to make up for the higher production-related emissions as compared to their ICEV counterparts. They assumed a total travel distance of 200,000 km during the car's lifetime, which resulted in BEVs having a 20%-27% lower lifecycle impact than ICEVs. However, they also found that the electricity mix that is utilized when charging BEVs is vital for the lifecycle impact. Depending on the electricity mix, the impact could be either reduced even more compared to ICEVs, or it could even become higher than the ICEVs, if BEVs were charged with electricity produced by burning coal. There are also findings by Gröna Mobilister (2023) showing that a big electric SUV emits approximately 55% more CO₂ than a normal-sized car in the golf class, emphasizing the importance that the size of the vehicle has on the climate impact (Per Östborn, 2023).

The trend of consumers purchasing larger cars can be seen in Sweden as well. Between the years 1975 and 2010, the vehicle mass (vehicle mass is used throughout this report to denote the mass in running order of a vehicle) of a car increased by 350 kg or 30% on average (Sprei & Karlsson, 2013). Meanwhile, the specific fuel use decreased by 38%. The trend of SUVs accounting for a larger share in new car sales can be observed in Sweden as well. In 2023, SUVs accounted for 48% of the new registrations of cars in Sweden (Olander, 2023). This trend can also be seen clearly in the top 10 most-sold car models in Sweden for the year 2024, where 7 were SUVs (Mobility Sweden, 2025). Sweden also has the heaviest car fleet on average in the EU, with an average vehicle mass of 1,836 kg (ICCT, 2023).

Since larger-sized cars have a bigger impact on the environment, an option for decreasing lifecycle impacts on the environment by the transport sector would be to downsize. In addition to reducing emissions during production, reducing vehicle size can potentially reduce the demand for critical materials necessary for battery manufacturing while improving energy efficiency (Morfeldt et al., 2024). However, in a study from the US, consumers were asked about their interest in downsizing and only about one-third of SUV drivers or SUV intenders indicated that they would be interested under specific conditions (Axsen, J. & Long, Z., 2022). The main reasons for not wanting to downsize were stated to be reduced cargo

capacity, reduced hauling capacity, reduced safety, and a dislike of the image of smaller vehicles. Hence, there seem to be barriers to downsizing, which are both physical and psychological. Assessing this potential solution requires a deeper understanding of how consumer preferences around vehicle size influence their choices and what implications this has for the electrification of the vehicle fleet.

1.1 Purpose

This project aims to increase the understanding of how consumer preferences regarding vehicle size affect material needs, energy use, and carbon dioxide emissions in connection with the electrification of passenger cars in Sweden.

The aim is met by answering the following research questions:

1. What factors influence consumer preferences when buying a car, and how do they impact the size of the vehicle?
2. What are the potential savings on raw material demand, energy use, and CO₂ emissions if vehicle downsizing becomes achievable?
3. What policies, incentives, or societal shifts would be necessary to encourage a shift towards vehicle downsizing?

The project results are expected to be useful for informing policymakers and manufacturers as well as raising awareness among consumers.

1.2 Delimitations

The scope of the project was constrained by:

- mainly focusing on consumer preferences within Sweden,
- limiting the analysis to only considering passenger cars, and

2 Method

To answer the research questions regarding consumer preferences and their impacts on vehicle size, energy use, material consumption, and associated emissions, a mixed-methods approach was used. The methods that were used include a literature review, statistical analysis, expert interviews, and a specific energy use model. Each of these methods contributes unique insights into the questions. The literature review establishes existing knowledge about consumer preferences by looking at previous research, mainly surveys. The statistical analysis has a much more focused approach on Sweden and the trends and correlations that can be seen based on demographics and vehicle data. The expert interviews provide valuable insights from experts and stakeholders within the transport sector. The specific energy use impact assessment makes it clear which benefits could be gained from downsizing in terms of energy savings, both during the use phase and the production phase. Together, these methods offer a broad and deep understanding of the issue, making it possible to form a solid basis for the conclusions and policy recommendations.

2.1 Literature Review

A literature study was conducted to investigate car purchasing preferences of consumers depending on their demographics. The main literature used is studies that include surveys exploring how demographics can affect the consumers' car preferences. Literature about perceived benefits and drawbacks of different vehicle sizes has also been studied to find barriers to realizing the downsizing potential. In addition, literature about lightweighting has been examined to understand how the potential future vehicles mass may change and what effects that could have, as well as literature on the topic of range anxiety.

The method that was mainly utilized during the research was chain-searching. This method is based on starting with a few recommended studies and following their sources and citations to find more material on the subject (Umeå Universitet Bibliotek. 2024). But at some points, this method did not yield the needed research, and then searching directly in databases became necessary. The databases used were Google Scholar, ScienceDirect, and ResearchGate. The keywords used to find relevant sources are listed below.

- Barriers
- Comfort
- Consumer

- Downsizing
- Perception
- Preferences
- Safety
- Size
- Status
- SUV
- Symbol
- Vehicle
- Willingness

These keywords were used and combined in different ways to search for new sources that later could be used for chain-searching.

The type of literature that was primarily used is scientific peer-reviewed articles, in combination with reports or articles from governmental authorities, companies, and non-governmental organizations (NGOs).

When reviewing the surveys, all factors that affected the size of the vehicles were gathered and compiled. Newer sources were given higher priority compared to older sources since trends that may have been prevalent 15 years ago may no longer apply. When older sources and newer sources disagreed, the newer sources were the ones considered. Older sources could, however, strengthen the reliability of newer sources and show that these trends have been prevalent for many years.

2.2 Statistical Analysis

A statistical analysis was conducted to investigate how trends have changed and to see which trends are present. The statistics used in this analysis come from the Swedish national vehicle registry combined with other registries to be able to connect a specific car purchase during a car's lifetime to an individual. Due to issues with confidentiality, the data was aggregated based on groupings of owners following different demographic characteristics. If the number of car purchases that fit into a group was less than or equal to 5, the data was removed due to risks of disclosing confidential data that may be used to identify individuals.

The statistics are provided for the years 2000-2021 and include data on purchases from the vehicle registry for the years 2014-2021. Data that has to do with socioeconomic status, such

as income, living area, housing type, and household type, will therefore come from 2014 and later, even if the car was bought earlier than 2014. This introduces uncertainties on the income, population density, household type, and housing type of individuals if the purchase occurred before 2014. As an example, if a car was bought before 2014 but the data was extracted at a later year, the income, living area, household size, and housing type data will be for the year it was extracted from the vehicle registry. As a result, the findings related to income in earlier years should be interpreted with caution. This will likely impact the result for income the most. This does not impact gender or age at purchase. For each vehicle entry in the registry, the last three owners can be identified and have been matched across the years to create ownership chains for the analyzed vehicles. Since the analysis focuses on consumer preferences for purchases that are long-lasting, all data that corresponded to an ownership time of less than 30 days were removed. The analyzed vehicles include all vehicles that were in traffic, retired or exported during the period 2014-2021. The aggregated data include which car type, time since it was sold to the first buyer, mean vehicle mass including the confidence interval (95%) as well as the number of observations. The statistics focus on privately owned cars. Company-owned cars were also included but only in a few variables. The variables that were included were income in the form of income quartiles, population density in the form of four categories ranging from rural to urban, household type, housing type, gender, age at purchase, age of car at purchase, and environmental classifications. These variables were analyzed individually, which introduces risks of correlation between variables. For all variables, the analysis distinguishes between the secondhand market and new car sales.

Table 1: Description of included aggregated data for each purchase.

Year of purchase	2000-2021.
Car type	ICEV-Gasoline, ICEV-Diesel, ICEV-Methane, PHEV-Gasoline, ICEV-Ethanol, BEV, PHEV-Diesel and Other.
Time since first sold	Less than one year or all purchases.
Mean mass in running order	Mean vehicle mass and confidence interval (95%).
Number of observations	Number of observations for the aggregated group.

Table 2: Description of studied variables.

Income	In the form of income quartiles with the lowest-income individuals being in quartile 1 and the highest-income individuals appearing in quartile 4.
Population Density	Categorized based on the population density of the DeSO-zone of the individual. Population density levels include (based on definitions by Hanberry 2022): rural (less than 15

	inhabitants/km ²), exurban (15-550 inhabitants/km ²), suburban (550-1,900 inhabitants/km ²), and urban (more than 1,900 inhabitants/km ²).
Household Type	Include singles without children, singles with children below the age of 25, singles with children above the age of 24, cohabiting without children, cohabiting with children below the age of 25, cohabiting with children above the age of 24, other households without children, other households with children below the age of 25, other households with children above the age of 24
Housing Type	Include categories apartment building ownership (ab own), apartment building condominium (ab con), apartment building rental property (ab ren), other accommodation (other), house ownership (h own), house condominium (h con), house rental property (h ren), special housing for the elderly and disabled (spec ed), special housing other (spec o) and student accommodation (stu a)
Gender	Either Man or Woman
Age at Purchase	In the form of age groups including <18 years, 18-30 years, 30-40 years, 40-50 years, 50-60 years, 60-70 years, and >70 years.
Age of Car at Purchase	In the form of age groups including <1 year, 1-17 years, 17< years, and All.
Environmental classes	Including MB2007 and MB2013.

The database from which this data came includes both cars that have been scraped by 2022 at the latest and cars that are still in the car fleet. In the later years of the data, the sample sizes decrease quite a lot due to lower sales to private individuals, making the confidence interval become quite big in the last years. There is also quite a small sample for some car types which results in drastic jumps in mean vehicle mass values which leads to confidence intervals of 95% overlapping with each other, therefore the focus of the statistical study is on ICEV-Gasoline cars and ICEV-Diesel cars since they make up the largest shares of the car market during the analyzed years and provide large sample sizes for all years.

Since there is no access to the underlying microdata, a t-test to determine statistical significance can't be conducted. Instead, Cumming & Finch (2005) suggest using inference by eye to decide whether a result is statistically significant. If no overlapping of confidence intervals occurs between two groups, then that suggests that the p value is less than 0.01. However, some assumptions need to be made for this, including that the sample sizes are at least 10 and that the confidence intervals' widths do not differ too much from each other. But this method still gives a good approximation of the significance level.

2.2.1 Data from EEA

For comparison, data from the European Environment Agency (EEA) was analyzed to see if the two data sets had similarities. The data from EEA includes new petrol passenger cars registered in Sweden and stretches from 2010 to 2023 (European Environmental Agency, 2024). There was a problem with the EEA data. The number of observations from 2010 up to and including 2017 was quite small, only including between 3795 to 6299 per year. From 2018 forward, the number of observations increased to between 20,000 and 190,000 per year. Therefore the years before 2018 might not be that accurate since it is unclear which vehicles they have included.

When comparing the two data sets the vehicle mass is a bit different with the data from the Swedish national vehicle registry showing heavier cars than EEA from 2018 forward. The comparison can be seen in Figure 1.

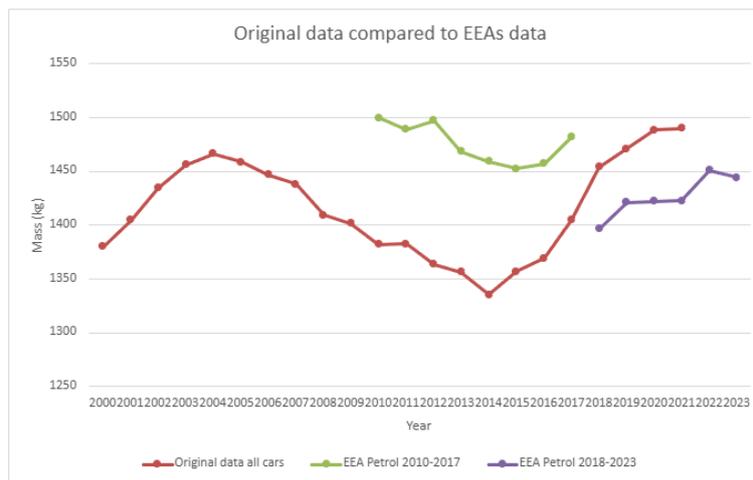


Figure 1: Comparison of data sets from the Swedish national vehicle registry and EEA for new gasoline passenger cars. The red line is the data from the Swedish national vehicle registry, which also represents new gasoline passenger cars, the green line is the data from EEA up until 2017, and the purple line is the data from EEA from 2018 up until 2023.

The difference in 2018 is approximately 58 kg, while in 2021 the difference is 67 kg. There seems to be an increase in mean vehicle mass in the EEA data as well, but not as drastic as the data from the Swedish national vehicle registry indicates. Mild hybrids are included in the data from the Swedish national vehicle registry, but they are excluded from the EEA data. This will result in a vehicle mass difference between the data with the data from the Swedish national vehicle registry, showing heavier cars on average.

For reasons such as incomplete data before 2018 this data will not be used during the statistical analysis.

2.3 Expert Interviews

Input from experts can be a great tool to understand how preferences may affect the size of vehicles, how trends change over time, what potential there is in downsizing cars, and how likely this potential could be realized. To get this information from a wide range of experts and to easily compare the findings of the interviewees a semi-structured formula for the interviews was used. Experts to interview were discussed and chosen together with the project's reference group (the supervisor, the examiner, and a representative from Swedish Society for Nature Conservation). To plan and set up the semi-structured interviews the article “Focus on Methodology: Eliciting rich data: A practical approach to writing semi-structured interview schedules” by Bearman, M. (2019) was used as guidance.

Bearman (2019) emphasizes the importance of structuring the interview by starting with some warm-up questions and providing context for the interviewee to make them comfortable. After that, the interviewer can delve into the main questions. Finally, at the end of the interview, it is a good idea to ask the interviewee if they have any final thoughts or comments that they would like to share. The interviewer should also try to avoid yes or no questions and aim to use open-ended questions to allow for more detailed responses. It is also of higher interest to know the stance of the organization that the interviewee is representing than the thoughts of a single individual, who may have their own beliefs. Therefore, there is a high emphasis on what the organization's standing is and not the individual who is being interviewed. For example, instead of asking “What do you think about this issue?” the question is formulated as “What does your company think about this issue?”.

A manuscript was created to support the interviewer during the interviews. The manuscript included a presentation of the context of the interview as well as warm-up questions and main questions split up into three themes. These themes include consumer preferences, trends within the transport sector, and possibilities and hindrances for downsizing. The manuscript (in Swedish) is provided in Appendix A.

The limitation of the semi-structured approach is that there can be no changes in the main questions between the interviews. If it were to be noticed after the first interviews that additional questions would have yielded better results for the thesis, it is not possible to change this after the first interviews have been conducted to give all interviewees the same chance to answer.

In Table 3 below, all the interviews that were carried out for this report are listed. The table includes information about who was interviewed, which company or organization they work for or represent, when the interview took place, and approximately how long the interview was. All interviewees have given their consent to be mentioned by name in the report.

Table 3: Information about the interviews.

Name	Company/Organization	Date of interview	Time of interview
Helen Lindblom	Swedish Transport Administration	28/2	45 min
Joakim Dahlman	VTI	3/3	45 min
Jan-Erik Swärdh	VTI	5/3	60 min
Staffan Algers	TPmod AB	6/3	45 min
Marielle Aspevall	Swedish Society for Nature Conservation	6/3	30 min
Carl-Erik Stjernvall	National Association of Motor Vehicles in Sweden	10/3	70 min
Mikael Levin	Transport Analysis	12/3	40 min
Lars Malmek	Volvo	25/3	70 min

2.4 Specific Energy Use Impact Assessment

The specific energy use modeling is done to be able to assess the impact of vehicle mass in running order and vehicle frontal area on the specific energy use of different vehicles. To model the specific energy use of vehicles the Worldwide Harmonized Light Vehicles Test Cycle (WLTC) was used as an attempt to model real-world driving (Cox et al. 2020). The WLTC is 30 minutes long where the car drives in 4 different phases from 0 km/h to around 130 km/h with different segments of breaking and stopping included. With this information, the acceleration and power output can be calculated. The formulas used to calculate the power needed are acceleration, air resistance and rolling resistance.

$$P_a = a(t) \cdot m \cdot v(t) \quad (1)$$

Where P_a is the acceleration power (W), a is the acceleration (m/s^2), m is the mass (kg), and v is the velocity (m/s).

$$P_{ar} = \frac{v(t)^3 \cdot C_d \cdot A_F \cdot \rho_{air}}{2} \quad (2)$$

Where P_{ar} is the air resistance power (W), v is the velocity (m/s), C_d is the aerodynamic drag coefficient, A_F is the frontal area (m^2), and ρ_{air} is the air density (kg/m^3).

$$P_{rr} = g \cdot m \cdot C_r \cdot v \quad (3)$$

Where P_{rr} is the rolling resistance power (W), g is the acceleration due to gravity (m/s^2), m is the mass (kg), C_r is the rolling resistance coefficient, and v is the velocity (m/s). By utilizing these three equations, the total power can be calculated. Since BEVs can also have regenerative breaks there are some conditions for the power needed.

$$P_t = \begin{cases} P_a + P_{ar} + P_{rr} & \text{if } P_a + P_{ar} + P_{rr} > 0 \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

$$P_b = \begin{cases} P_a + P_{ar} + P_{rr} & \text{if } P_a + P_{ar} + P_{rr} < 0 \text{ and } V \geq 5 \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

Here, P_t is the power traction (W) and P_b is the power breaking (W), with V representing the velocity in kilometers per hour. When the power is calculated the energy requirements can be calculated if efficiencies for the engine, drive train, battery discharge, and regeneration two-way are known.

$$E_{WLTP} = \frac{\sum_{t=0}^{1800} (P_t + P_b \cdot \eta_{rt})}{\eta_e \cdot \eta_d \cdot \eta_{bd} \cdot s \cdot 1000} \cdot \frac{1}{3.6} \quad (6)$$

E_{WLTP} (Wh/km) represents the specific energy use according to WLTP, η_{rt} is the regeneration two-way efficiency, η_e is the engine efficiency, η_d is the drive train efficiency, η_{bd} is the

battery discharge efficiency, and s is the distance in meters. For ICEV the equation looks like this instead since ICEVs doesn't have a regenerative braking.

$$E_{WLTP} = \frac{\sum_{t=0}^{1800} (P_t)}{\eta_e \cdot \eta_d \cdot s \cdot 1000} \cdot \frac{1}{3.6} \quad (7)$$

Equation 7 is a simplification of reality, however, made in line with the model developed by Cox et al. (2020). In reality, the efficiency of an ICE varies with the engine speed (the rpm). The calculations are made for ICEV cars and not mild hybrids. In the article by Hussein Alhayali (2015), a single cylinder spark-ignition engine was tested showing that the efficiency of the engine varied with the engine speed.

When the specific energy use according to the Worldwide Harmonized Light-Duty Vehicles Test Procedure (WLTP) is calculated, the final step to get an assumption of the real-world specific energy use is to multiply the result from the WLTP with a factor, C_{rw} , that accounts for real-world driving conditions not covered by the WLTP (Morfeldt et al. 2025).

$$E = E_{WLTP} \times C_{rw} \quad (8)$$

Here, E represents the specific energy used (Wh/km), and C_{rw} represents the correction factor. With this model, three different car types were tested including BEVs, ICEV-gasoline cars and ICEV-diesel cars. The data for these three car types are presented in the table below.

	Current BEV	Current ICEV-g	Current ICEV-d	Source
$g \text{ (m/s}^2\text{)}$	9.81	9.81	9.81	
Mass (kg)	1895	1558	2082	Statistical findings Section 4. Mean vehicle mass for the year 2021.
Aerodynamic drag coeff	0.3	0.3	0.3	Cox et al. 2020
Frontal area (m ²)	2.3	2.3	2.3	Cox et al. 2020
Rolling resistance coeff	0.01	0.01	0.01	Cox et al. 2020
Air density (kg/m ³)	1.225	1.225	1.225	Cox et al. 2020
Engine efficiency	0.85	0.25	0.29	Cox et al. 2020
Drive train efficiency	0.85	0.80	0.80	Cox et al. 2020

Battery discharge efficiency	0.88	-	-	Cox et al. 2020
Regeneration two-way efficiency	0.7225	-	-	Cox et al. 2020
C_{rw}	1.1	1.2675	1.19	Komnos et al. 2022

Table 4: Data for each base car type.

The C_{rw} values were gained by taking the result from Komnos et al (2022) range of the gap between the worst and best case and dividing that gap by 2 to get a representable value of how much real-world energy needs differs from the WLTP.

3 Findings from Literature Review

Understanding the preferences of consumers plays an important role in understanding the possibilities for the downsizing of cars. Surveys can be a great tool for finding the preferences of consumers, and for hearing their opinions and reasoning. For this reason, studies that have conducted surveys have been explored to find which preferences are prevalent among consumers. The studies take place in several different places, but mainly in North America and Europe.

In Table 5, a summary of the literature including surveys can be found. For each study the geographical location is presented together with the sample size of respondents, explored vehicle characteristics, and respondent characteristics. The main findings from each survey are also presented and the key demographics that the results depend on in the surveys. In cases when demographic dependency was unclear, and the findings could be classified as more general, the term household was used as a demographic.

These surveys took place in several different countries and over several years. The oldest survey comes from 2008 in Wellington, New Zealand, which may therefore not have the same value as newer surveys. To find a result for how demographics shape preferences for consumers a compilation of all study results is necessary as well as a comparison between the findings of these studies.

Table 5. Summary of survey studies examined.

Study and Geographical location	Sample size and Method	Vehicle characteristics examined	Key demographics	Key findings
Sovacool et al., 2018. Nordic region	5,067 individuals. Online survey as a structured questionnaire. 44 total questions.	Speed/ acceleration, size/ comfort, design/ style, ease of operation, technical reliability, safety, fuel economy/ financial savings, price, environmental impact, Range, Battery life, Public Charging, Charging time, V2G	Occupation, Household size, Age	No gender difference in car size preference. Education has a low impact on vehicle size. Retirees prefer smaller cars; private sector workers prefer larger cars. Preference for large vehicles increases with household size and peaks at age 35-44.
Baltas, G. & Saridakis, C., 2013. Europa	1,622 individuals. Large-scale survey research.	Cost, Technical, Performance, Image, Quality, Interior, Driving, Equipment, Vehicle type	Gender, Income, Education level, Residential area	Males prefer SUVs over smaller cars. High-income individuals favor SUVs. Higher education leads to a preference for small family cars. Urban residents prefer luxury and large family cars over SUVs. Individuals who put a big importance on social status are more likely to prefer expensive cars.
Higgins et al., 2017. Canada	15,392 households. Online survey split into six parts. Exploring 7 different car body types.	Excellent Fuel Economy, Reduced Tailpipe Emissions, No Tailpipe Emissions, Performance, Luxury Styling, Passenger Room, Ample Cargo Space, Maintenance Cost, Technology, Vehicle Type	Household size, Income, Amount of children, Education, Residential area, Travel distance	Individuals who live in smaller households, with lower income, and few children, importance of fuel economy and importance of reduced tailpipe emissions prefer economy cars. Individuals with high income, high education, and living in urban areas prefer luxury cars. Individuals who live in rural areas, with lower education, younger households, long travel distances, and focus on cargo space prefer pickups.

<p>Engström et al., 2019. Sweden</p>	<p>2,258 individuals. Questionnaires were sent to private car buyers and individuals with benefit cars (i.e., company cars provided as part of employment benefits). Responses were weighted by statisticians to reflect the socio-demographics of the population.</p>	<p>Vehicle type, Fuel Type, Size, Market Preferences, Cost Factors</p>	<p>Household size, Private car buyers, Individuals with benefit cars</p>	<p>Household size over one adult prefers family cars over small cars. Individuals with benefit cars always prefer family cars over small cars. Willingness to pay for larger cars is higher for benefit cars.</p>
<p>Axsen, J. & Long, Z. 2022. Vancouver. Canada</p>	<p>986 individuals. Online survey split into 5 sections.</p>	<p>Vehicle size, Performance, Functionality, Fuel efficiency, Environmental impact, Social Perception</p>	<p>Non-driver, Car driver, SUV driver</p>	<p>SUV drivers prioritize cargo space, snow-driving capability, and "fun to drive" factors. Non-SUV drivers value fuel efficiency more. Both value price, saving money, comfort, safety, ease of use, reliability, and increased quality of life. No statistically significant difference between non-SUV drivers and SUV drivers when it comes to assigning importance to symbolic motivation for their choice of car. Half of the participants stated that SUVs can be seen as a status symbol.</p>
<p>Cirillo et al., 2017. Maryland. USA</p>	<p>456 households. A stated preference survey.</p>	<p>Hybrid, Vehicle size, Vehicle MPG, Model year,</p>	<p>Household</p>	<p>Households prefer larger vehicles for both ICEVs and EVs, preference for larger BEVs is higher than for ICEVs. Willingness to pay for larger BEVs is higher than for ICEVs.</p>

				Willingness to pay for increased MPG is higher for ICEVs than for EVs.
Alkan, N., & Koksal, C.D., 2024. Anatalya. Türkiye	405 individuals. Face-to-face survey with consumers who wanted to buy a car, 16 questions.	Brands, Design, Price, Fuel consumption, Luggage capacity, Safety systems, Comfort	Gender, Age, Income	Safety systems and low fuel consumption are the most important aspects. Comfort, price, and design are also important. Environmental concerns are less important.
Thomas, J.A. & Walton, D., 2008. Wellington. New Zealand	496 individuals. The questionnaire had 133 questions to examine attitude toward vehicle size, safety, household characteristics, vehicle characteristics, driver characteristics, and other demographic information.	Vehicle type, Vehicle size, Safety	Car driver, SUV driver, Household size, Income, Gender, Number of Vehicles	SUV drivers were males to a larger degree, had higher income, had more children, and more vehicles. SUV drivers state off-road capabilities and family needs as main reasons for owning SUVs. SUV drivers see their cars as safer than normal cars. Drivers purchase “safety” through a larger vehicle. SUV owners believe SUVs have a positive effect on road safety. SUV owners highlighted comfort as important. SUV owners place a high importance on price of the vehicle, saving money, safety, and quality of life.

Preference for larger vehicles increases with household size and peaks for households with more than five members (Sovacool et al., 2018). This trend aligns with the 35–44 age group, where household sizes are typically larger. Engström et al. (2019) found that multi-adult households favor family cars, while Thomas & Walton (2008) noted that SUV owners tend to have more children. While household size strongly influences vehicle choice, younger individuals are more environmentally conscious and may therefore be more receptive to downsizing policies (Sovacool et al., 2018).

Income, occupation, and education also seem to play important roles. Higher-income individuals consistently prefer larger, more expensive vehicles, while lower-income consumers prioritize fuel economy and cost. Occupation and education also seem to indicate this in most of the studies. When individuals acquire higher-paid work or better education a preference for more expensive and larger cars follows. Except in the study by Baltas & Saridakis (2013), where the authors state that higher education leads to a preference for small family cars over SUVs, but, at the same time, they found that a higher income leads to a preference for SUVs over smaller cars.

Place of residence can potentially also affect the preferences of consumers. People living in urban areas prefer large family cars and luxury cars over smaller cars, indicating that fuel-efficient transportation methods aren't that important (Baltas & Saridakis, 2013). People living in rural areas also prefer larger vehicles. The groups who prefer pick-up trucks mainly live in rural areas, where cargo space has a higher importance (Higgins et al., 2017).

One of the factors that makes people more likely to pursue smaller vehicles is the fuel economy of the acquired car. Fuel efficiency was shown to have a positive effect on downsizing (Sovacool et al. 2018). Gender, lower income, and occupation affect the priority of fuel efficiency, with women, people with a lower income, and students showing clear signs of a preference for high fuel efficiency. It was also shown that consumers who purchased cars in the economy section placed the highest importance on fuel efficiency (Higgins et al. 2017).

3.1 How Demographics Shape Preferences

In several earlier studies, the impact of demographics has been examined to show how different groups differ in their vehicle preferences. The demographics that have been studied include gender, education level, form of employment, age, and household size (Sovacool et al., 2018). But also, income and area of residence (Baltas & Saridakis, 2013).

Sovacool et al. (2018), distributed a survey to a total of 5,067 people in the five Nordic countries. They found that there were differing preferences for the size of the cars depending on demographics. They found that there was no difference in preference for size between men and women, they ranked the size and comfort of the vehicle equally. At the same time, women rank categories like safety, price, fuel economy, and environmental concerns more highly than men. Education level didn't seem to affect the preference for vehicle size either. When it came to employment, it was clear that retirees had the lowest preference for large cars, while people in the private sector had the highest preference for large cars. Students gave the highest importance to fuel efficiency and people in the private sector gave it the lowest. It becomes clear that the personal finances of individuals taking the survey plays an important role. The lower the income, the higher importance is placed on purchasing price and fuel economy and less on technical reliability and environmental concerns. For consumer preferences among different age groups, there was an increase in the mean vehicle mass until the age group 35-44, and after that, it started to fall again. Younger people aged 25-34 are also the ones with the highest interest in EVs, which is expected since they gave a high importance to the environmental impacts of cars. The group aged 45-64 were shown to have a higher daily travel distance and a lower interest in environmental concerns. Therefore, they also show a lower interest in EVs. This age group generally scores BEV range and public charging as more important than other groups, indicating that they expect reliability from their cars. When comparing consumer preferences among different household sizes, the preference for larger vehicles increased until the 5+ category, where the size preference increased sharply, likely since most cars just have five seats. It was also clear that the importance of safety became much higher for households with 3 or more individuals.

Baltas & Saridakis (2013), analyzed the result of a European survey with 1,622 participants to find correlations between certain demographics and preferences. They found that males are less likely to prefer mini cars, super-mini cars, station wagons, and multipurpose vehicles compared to SUVs. People with a higher monthly income are more likely to prefer SUVs over mini cars, super-mini cars, and medium-sized cars, while a higher education makes it more likely that they prefer small family cars. Individuals who put a higher importance on cost characteristics tend to prefer medium-sized cars perhaps since they are cheaper and more fuel efficient than other alternatives. People who live in urban areas are more likely to prefer large family cars, luxury cars, multipurpose vehicles, and coupes to SUVs.

Higgins et al. (2017), analyzed the results of a survey of 20,520 households in Canada in 2015. The survey asked the participants which type of car the household would be most interested in acquiring, as well as other questions about their background. They found that households that prefer cars in the economy segment were smaller, on average, with lower incomes and the least number of children. The households that prefer economy cars also place the highest importance on fuel economy and on reduced/no tailpipe emissions. However, those households do not prioritize other attributes like styling, performance, passenger room, and cargo space. It was also clear that the ones pursuing luxury cars had the highest income, had the highest level of education, and were most likely to live in urban areas, on average. They own the largest number of vehicles, and this group features the smallest number of females out of any of the groups. In comparison with households that prefer economy cars, they put little importance on fuel economy and maintenance costs while prioritizing styling, performance, and technology. The ones who prefer pickup trucks tend to live in more rural areas, have lower education, and be younger, but they report the highest traveled distance per year. Their focus is on cargo space, while they give little importance to tailpipe emissions.

Engström et al. (2019), found that a household size of over one adult prefers a family car over a small car, on average. However, for individuals with benefit cars, all households prefers family cars, even the households with just one adult. People with benefit cars also had a higher willingness to pay for larger cars; this resulted in benefit cars and private cars having similar average greenhouse gas emissions even though more "green vehicles" existed within the benefit pool.

Cirillo et al. (2017) found that all households prefer larger vehicles for both ICEVs and EVs, but the preference for larger battery BEVs is more significant than for ICEVs. The willingness to pay in order to increase the size of the BEVs was also higher than for ICEVs, consumers are thus willing to pay more to own a larger EV. The main concern that consumers have with BEVs seems to be that they were too small. The willingness to pay for increased miles per gallon (MPG) was higher for ICEVs than for EVs, which is likely related to BEVs already being very fuel efficient. Consumers in the US market prefer “newer vehicles with larger size, higher fuel economy, lower purchasing price, and lower fuel price”.

Axsen & Long (2022) explore the willingness to downsize from SUVs and found similar assigned importance to categories like price, saving money, comfort, safety, ease of use, reliability, and increased quality of life. However, individuals driving non-SUVs gave higher importance to fuel efficiency, and SUV drivers gave higher importance to spacious cars (large

capacity for passengers and cargo), as well as the ability to drive in snowy or wet conditions. SUV drivers also gave a higher importance to the category of “fun to drive”.

Thomas & Walton (2008) found that SUV drivers valued their cars for their off-road capabilities and practicality for family use. However, the majority of SUV drivers seldom used the off-road capabilities, and they were as likely to drop off children at schools as non-SUV drivers. Family needs and off-road capabilities may be used as a justification to own an SUV rather than the main reason. The drivers owning SUVs were males to a larger degree, had a higher total household income, were more prone to have more children, and were more likely to have a large number of vehicles. However, age was not a distinguishing factor. SUV owners were on average about 2 years younger with a mean of 44 years old.

Gender seems to have little effect on car size. More recent surveys suggest that there is no difference in preference for size between the genders, but there seems to have been a larger difference in older studies like those by Baltas & Saridakis (2013) and Thomas & Walton (2008), where it was clear that especially men preferred SUVs over smaller cars.

3.2 Vehicles as Status Symbols

According to Axsen & Long (2022), there is no statistically significant difference between non-SUV drivers and SUV drivers when it comes to assigning importance to symbolic motivation for their choice of car. About half of the participants in the survey conducted by Axsen & Long (2022) stated that SUVs can be seen as a status symbol, a symbol of success. Individuals who give high importance to social status are more likely to prefer expensive cars. This is especially true for luxury cars, cabriolets, and roadsters as they may be seen as symbols of status (Baltas & Saridakis, 2013). This also seems to be true within Sweden, but in that case families tend to prefer large cars as they symbolize status and welfare (Nykqvist & Nilsson, 2015). According to Thomas & Walton (2008), SUV drivers value their cars as a symbol of success and lifestyle to a higher degree than non-SUV owners, but this may not be true anymore since the study is almost 20 years old.

According to Vögele et al. (2021), both lower and middle income groups have preferences for generally larger vehicles, while the upper income group shows a trend especially towards SUVs, as the upper-class seems to be more receptive towards status effects. According to Vögele et al. (2021), SUVs seem to be associated with wealth, and therefore, individuals buy these cars to increase their social status since this is the norm within this group. The effect of SUVs being perceived as having high status has led to a higher preference for these cars.

3.3 Safety and Comfort

SUV drivers see their cars as functionally superior in terms of safety. SUV drivers seem to have an egocentric belief that SUVs are safer since they are bigger, and bigger is safer (Thomas & Walton, 2008). There is a belief that the physical size of the vehicle is more important than the mass or height when it comes to safety. Meanwhile, it has been shown that an increase in vehicles sizes decreases the safety of the transport system. The likelihood of a fatal car crash increases by 12% for every 500 kg difference between the vehicles that crash (Shaffer et al. 2021). SUVs are also more prone to accidents related to rollovers and loss of control because of the higher center of gravity (Thomas & Walton, 2008). It was also found that an increase in vehicle height by only 10 cm resulted in an average increase of 30% for fatal injuries when hitting pedestrians and cyclists (Godart, 2023). Still, safety is stated as one of the main reasons for purchasing a larger vehicle in the US. Generally, drivers perceive their driving ability as safer than the typical driver, so instead of changing their driving style, they can purchase "safety" through a larger vehicle that they believe is safer (Thomas & Walton, 2008). This may also explain why SUV owners are more likely to think that SUVs have a positive effect on safety within the transport system, even for pedestrians and cyclists (Axsen & Long, 2022).

Better visibility by sitting higher up is the main reason that SUV owners state for feeling safer, as well as the fact that they would feel more protected if a crash occurred (Axsen & Long, 2022). Safety systems are also stated as one of the most important systems in new-generation cars (Alkan & Koksai, 2024). According to Thomas & Walton (2008), policymakers should try to reduce the false perception of the safety associated with larger vehicles, switching advertisements from personal protection to overall protection within the transport system.

The comfort of a bigger car also seems to be one of the contributing reasons for acquiring a larger car. It was found that SUV owners thought of their cars as comfortable and that they assign similar importance to this attribute as the price of the vehicle, saving money, safety, and quality of life (Axsen & Long, 2022). It was also prevalent that low- to middle-income classes were more focused on comfort, price, and fuel consumption than high-income individuals who had a higher focus on social norms. Comfort also had a negative effect on the willingness to downsize, while fuel efficiency had a positive effect. Individuals were generally not willing to give up size and comfort when purchasing a new vehicle, but they still

wanted lower fuel consumption (Sovacool et al. 2018). According to Alkan & Koksal (2024), comfort is not the most important feature, while safety systems and low fuel consumption instead take the place of the most important aspects. However, comfort is still a very important feature of new-generation cars, as is the price and design of the car. In decision-making, it seems like environmental concerns are less important for most consumers. Younger people were also observed to follow technological developments within the automotive sector more closely, which may make them more open to alternative vehicle types.

3.4 Range Anxiety and Battery Size

Another factor that increases the size and weight of batteries and ultimately also the vehicle mass is range anxiety (Poupinha & Dornoff, 2024). BEVs reduce the drivers' freedom to move and their autonomy, which provokes stress in drivers (Rainieri et al., 2023). This phenomenon is known as range anxiety, which describes the driver's fear of running out of electricity before reaching their destination. According to Poupinha & Dornoff (2024), almost 60% of the European population has stated that a minimum driving range of 500 km is necessary for them to consider adopting an EV. Therefore, larger batteries are needed in order to meet this requirement. But this, of course, leads to increased energy needs, material demand, and greenhouse gas emissions. A study of the Nordic region, found that 25% of people stated that the "limited range of electric vehicles" was the reason for disinterest in BEVs even though the daily average travel demand for 93% of these individuals was below 80 km per day (Noel et al. 2019). Therefore, range anxiety is found to be more of a psychological barrier than a technical barrier to reduce the weight of batteries and ultimately the car. The limited range may be considered to endanger an existing way of life for many people who are used to ICEVs. At the same time, it seems like exposure to BEVs reduces the range anxiety within the first 3 months (Rainieri et al., 2023).

However, range anxiety may not be the most significant barrier for BEVs since the range of most BEVs is more than enough to cover most daily trips (Rainieri et al., 2023). Many manufacturers also make it possible to choose the size of the battery capacity of the car to accommodate the needs of the customer. According to Noel et al. (2019), the best way to succeed with a high level of BEV adoption may be to ignore range anxiety and instead focus on other barriers to attracting additional consumers. Incentives like free tolls and free parking may overall result in a higher BEV adoption rate.

3.5 Legislation, Subsidies and Taxes

Cash incentives are consistently valued across vehicle sizes, but they have the biggest effect on the consumers who purchase cars within the economy and intermediate categories (Higgins et al. 2017). A case that demonstrated this was the effects of the financial crisis in 2008. The crisis led to higher fuel prices and a drop in GDP, signifying a decline in the average standard of living and economic well-being. These two factors led to a lower amount of vehicle kilometers traveled on average in Sweden (Bastian & Börjesson, 2015). But some have also pointed out that the importance of additional factors, such as changes in lifestyle, preferences, and attitudes to car travel, has been important in changing this. Bastian et al. (2016) mean that this is not true, and that GDP and fuel prices are sufficient to explain the changes in all countries they studied, including Sweden.

Recommendations to promote fuel-efficient vehicles include purchase taxes, feebates (a combination of a tax and a subsidy that rewards consumers who purchase more fuel-efficient vehicles and penalizes those who purchase less fuel-efficient vehicles), vehicle excise duty (VED) (annual road tax to use public roads) (Brand et al. 2013). In the article by Brand et al. (2013), feebates were found to be the most effective policy measurement in reducing life cycle emissions, and it could avoid overburdening consumers with taxes while still maintaining a neutral revenue. The simulation results by Haan et al. (2009) suggest that while feebates lead to reductions in specific energy use and emissions, they didn't lead to a decrease in vehicle size. Consumers were more inclined to switch to more energy-efficient cars instead of downsizing. Feebates did on the other hand have a high acceptance among consumers, which could possibly be attributed to it being a revenue-neutral scheme. VED was also proven to be a successful way to reduce emissions. However, since this policy leads to revenue for the government, it may also lead to opposition from consumers and car lobby groups. Therefore, Brand et al. (2013) recommend schemes that reward low-carbon options and penalize high-carbon options. It would also be wise to investigate current levels of fringe benefit taxes for company cars as these could lead to larger cars being purchased (Engström et al. 2019). Vögele et al. (2021) propose a weight-based taxation scheme where vehicles are taxed more depending on their vehicle mass or based on the amounts of CO₂ emitted per 100 km. The downside to this would, however, be that BEVs and hybrids are heavier than ICEVs because of their large batteries. Therefore, there is a need for differing taxation between the vehicle types.

Going beyond economic incentives, increasing the number of public charging stations could be an effective way to promote the adoption of EVs. This policy seems to mainly aim for people with cars in the economy and intermediate segments (Higgins et al. 2017). People who see their cars as symbols of status are less likely to be susceptible to such policies or other policies that target reduced use of fuels (Baltas & Saridakis, 2013). But if policymakers want to promote the ownership of smaller cars, they should focus on new drivers who are more susceptible to policies that try to promote the ownership of smaller cars. This is generally true for females and low-income earners as well, according to Baltas & Saridakis (2013).

4 Findings from Statistical Analysis

In the statistical analysis, the trends for purchases of gasoline cars and diesel cars (both ICEVs) were examined to better understand how different variables affect the mean vehicle mass. Since the socioeconomic data comes from 2014 and later even if the car is bought earlier one should not draw too strong conclusions based on data before 2014 for these variables. When analyzing the mean vehicle mass development for these two car types it becomes clear that newly sold cars for both car types have had an increase in their size since the year 2000. In recent years the newly sold cars have had a mean vehicle mass that is higher than the overall mean vehicle mass. This leads to an increase in mean vehicle mass for the private car fleet. New gasoline cars increased by around 14% in vehicle mass by 2021 compared to 2000 and diesel cars increased by approximately 36% over the same period. A similar trend can be seen for BEVs, which have increased in mass in running order by around 21% by 2021 compared to 2012, and PHEV-Gasoline cars, which have increased in mass in running order by around 36% by 2021 compared to 2004. The trend that vehicles get heavier and heavier is clearly shown in Figure 2. In 2021, ICEV-Gasoline cars weighed 1490 kg on average, ICEV-Diesel cars weighed 1,961 kg, BEVs weighed 2,100 kg, and PHEV-Gasoline cars weighed 1,906 kg.

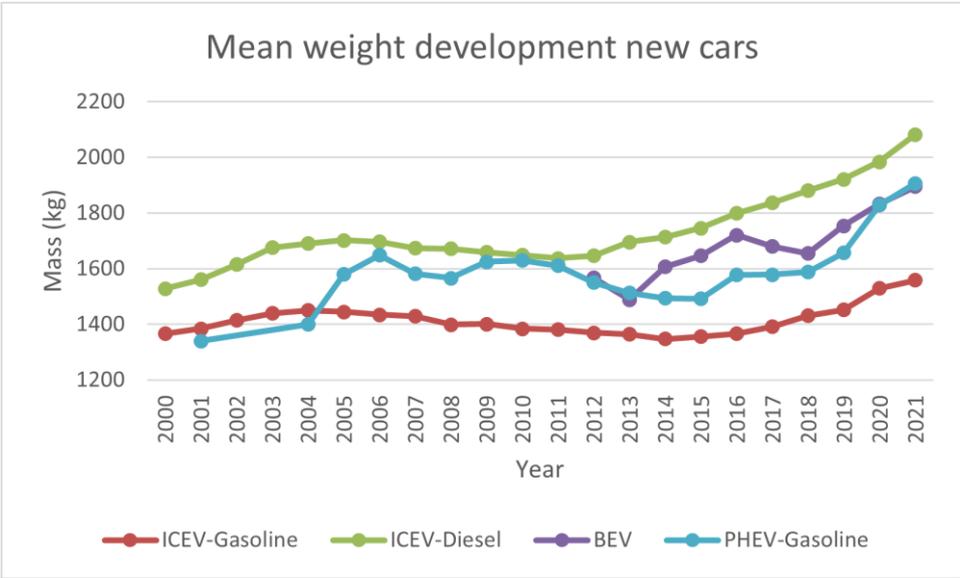


Figure 2: Mean vehicle mass development for newly sold ICEV gasoline cars, ICEV diesel cars, BEV cars, and PHEV gasoline cars.

The results gained from this statistical analysis show that many of the studied variables which are: income, population density, household type, housing type, gender, age at purchase, age of car at purchase, and eco labeling of cars have had a large impact previously but that this

impact has diminished in recent times. This is clear when analyzing the statistics for purchases of gasoline cars. The diesel car statistics are less certain due to their higher confidence intervals, but still show signs of similar trends as gasoline cars for many of the analyzed variables.

To summarize the findings, the variables that still have or have gained a large impact on consumers' preferences for car size are their geographical location (i.e., population density) and their housing type. The more urbanized your place of residence is, the more likely it is that you will purchase a smaller car (a deeper analysis on this can be found in 4.5). When analyzing the impact of consumers' housing type, consumers purchase larger vehicles if their housing is larger. People living in single-family detached houses purchase bigger cars than people living in apartments (a deeper analysis on this can be found in 4.7). The other variables show only a small difference in mean vehicle mass between the groups that have shrunk in the past 20 years, thus variables such as income, gender, household type, and age had a lower impact in 2021 than in the year 2000. Companies generally purchased heavier cars than private individuals, but this trend has started to shift in the last couple of years. Private individuals purchase heavier cars than companies since 2020, but there is also a much smaller portion of private individuals who purchase new cars now than during earlier years. Private individuals also have had a much more drastic development towards heavier vehicles in recent years than companies have (a deeper analysis on this can be found in 4.1). Overall, an increase in vehicle mass can be seen, and the persistence of this trend across both analyzed car segments highlights the need for some measure to change the trend if lighter and more sustainable cars are desired. In the following sections, the observed trends of each analyzed variable are explained in more depth. Graphs showing confidence intervals for each variable can be found in Appendix B.

4.1 Privately Owned Cars Compared to Company-Owned Cars

It is important to look at both privately bought cars and cars bought by companies since cars are sold back and forth between these groups on the second-hand market, and they therefore impact each other. When comparing privately bought cars and cars bought by companies, it is important to know which companies are considered. In this case, companies such as car dealers are not included in this data since they likely don't utilize the majority of the cars that are registered under them, since their business is to sell cars to other companies or private consumers. Car dealers are the only companies that are excluded from this data and the SNI2007-codes for these branches are the following: 45110, 45201, 45320, 38311, 38320,

46771, 46772, 46773. When looking at gasoline cars, private purchases stood for 72 % of all purchases in 2000, while in 2021, they only accounted for 26%. For diesel cars, private purchases accounted for 62% in 2000, and in 2021, they only accounted for 22% of all purchases. In the last years a switch has happened with private cars becoming heavier on average than company cars, and when looking at the development for all cars, including both privately bought ones and company bought ones, then the development is more of a middle ground as in Figure 3. Since the number of private consumers purchasing cars has decreased quite a lot in recent years, likely, the ones that can still afford to purchase a new car are also able to afford larger and heavier cars than the average consumer could have some years prior.

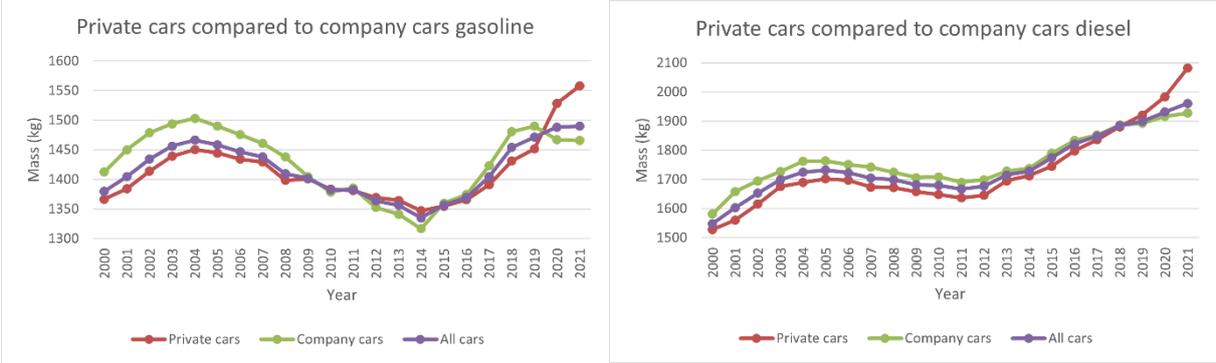


Figure 3: Mean vehicle mass development for ICEV cars when looking at new cars for both privately bought cars, company bought cars, and the whole fleet. The first (left) graph shows the development of gasoline cars. The second (right) graph shows the development of diesel cars.

4.2 Age of Car at Purchase

When analyzing the vehicle mass for purchases of cars, depending on the age of the car when it was purchased, some clear patterns can be seen both for gasoline cars and diesel cars. <1 represents newly sold cars while the other two categories represent to sides of the average lifespan of a car, which is 17 years. There is less and less difference depending on the age of the car. In Figure 4, the difference between cars older than 17 years and all the cars has decreased significantly, both for cars purchased by private individuals and for cars purchased by companies. While newly sold cars follow the same trend as when testing the other variables. From the graphs, a clear shift can be seen from 2014 up until today, with new cars sharply increasing in vehicle mass. The trend for the cars between the ages of 1-17 follows the trend that newly sold cars have, but delayed and not as drastic.

What can be seen is that cars bought by private individuals have increased significantly in mass since 2014, from 1,347 to 1,558 kg. During the same period, company cars went from 1,317 to 1,466 kg. While private purchases only account for about 26% of all new purchases in 2021 there for the fleet doesn't increase as much as privately bought cars. So what you can

see is that private individuals who buy new gasoline cars are buying larger ones than companies.

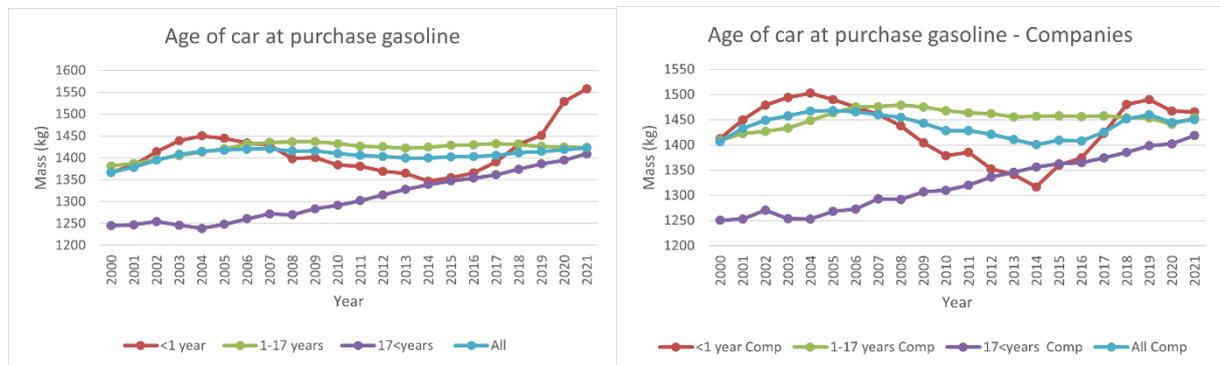


Figure 4: Mean vehicle mass development for ICEV gasoline cars when looking at the age of the car at purchase as a variable. The first (left) graph shows the development of cars bought by private individuals. The second (right) graph shows the development of cars bought by companies.

The same can be seen for diesel cars, but older diesel cars haven't increased to the same level as the rest of the fleet, likely since diesel cars increased a lot in mass less than 17 years ago, therefore, the larger cars haven't become older than 17 years yet. The same extreme vehicle mass increase can be seen for diesel cars after 2014, but at the same time, the sales numbers for diesel cars have diminished greatly in later years, and therefore, the whole diesel fleet isn't affected to a large degree by this mass increase in recent years.

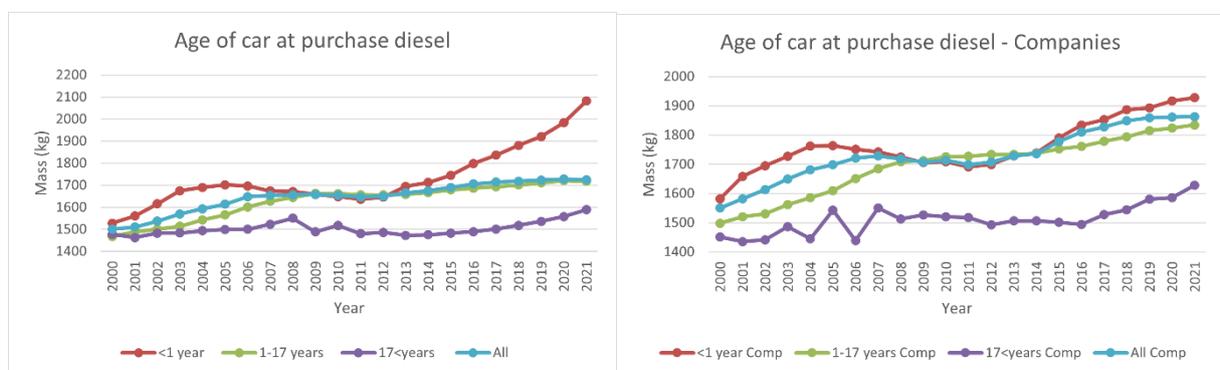


Figure 5: Mean vehicle mass development for ICEV diesel cars when looking at the age of the car at purchase as a variable. The first (left) graph shows the development of cars bought by private individuals. The second (right) graph shows the development of cars bought by companies.

From these statistics, both for gasoline and diesel cars, private consumers purchase heavier new cars than the companies do in the last years and that the mass increase is much more drastic when looking at privately bought cars. However, there are also fewer cars being bought by private consumers.

4.3 The Impact of eco-cars

The Swedish government has introduced environmental classes for cars during the years 2007 and 2013, but they were removed in 2022. These classifications are based on the amount of emitted CO₂ and particles. The MB2007 class had a limit of 120 g of CO₂ per km, and for diesel cars, an additional limit of 5 mg of particles per km (Sveriges Riksdag, 2025). There was also a limit on fuel consumption of 9,2 liters of gasoline per 100 km and 8,4 liters of diesel. If these criteria were upheld, a premium of 10,000 SEK was given to the consumer. After January 1st, 2013, they changed the requirements and made it weight-based. The new limit on CO₂ emissions became the curb weight minus $1,372 \cdot 0,0457 + 95$ (Ollevik, N, O., 2012). This implied that larger cars are allowed to emit more than smaller cars. If this criterium was upheld, a premium of at most 40,000 SEK could be given.

Cars classified as MB2007 cars were generally smaller and lighter to meet the requirements. MB2007 cars stood for at most 15% of the new sales of gasoline cars, with a peak in the year 2011. This may have resulted in the trend towards smaller and lighter cars that can be seen for new cars up until 2014. When this classification expired in 2013, the percentage dropped drastically to below 2% of newly sold cars. MB2013 never became widespread for gasoline cars, with at most 0.001% of new gasoline cars being classified as MB2013 cars. This could be one of the explanations for why gasoline cars increased in mass after 2014.

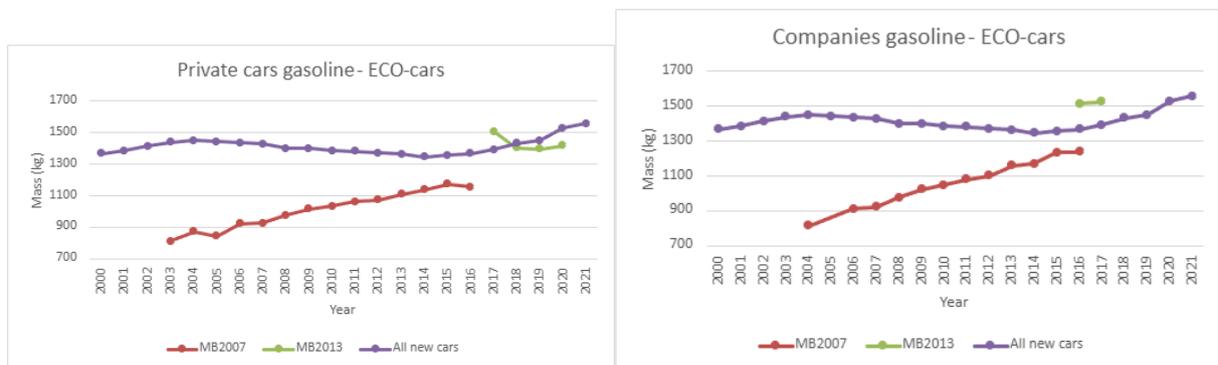


Figure 6: Mean vehicle mass development for newly sold ICEV cars when looking at environmental classes. The first (left) graph shows the development of privately bought gasoline cars. The second (right) graph shows the development of cars bought by companies.

When analysing diesel cars, a much higher percentage of the new cars being classified as MB2007 cars were found, peaking at 30% of new diesel car sales in 2011. They were also lighter than the average new car, as can be seen in Figure 7, therefore contributing to reducing the mean vehicle mass of new diesel cars. After 2013, when MB2013 came into force, there was a large decrease in the number of cars that could be classified as an eco-car, only a small

number of cars were classified as MB2013 cars. At the peak in 2016, approximately 13% of new diesel cars were classified as MB2013 cars. The number of new diesel cars being sold decreased drastically in the coming years.

For diesel cars, it seems like the MB2013 classification took over where MB2007 left off, continuing the same vehicle mass development trend that had been seen for MB2007 cars. Therefore, the environmental classification seems to have had a greater effect on the diesel than the gasoline segment.

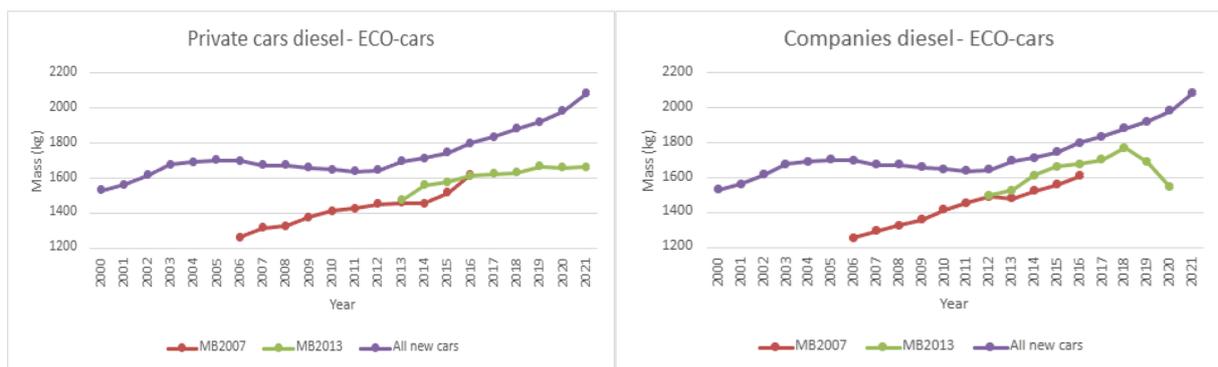


Figure 7: Mean vehicle mass development for newly sold ICEV cars when looking at environmental classes. The first (left) graph shows the development of privately bought diesel cars. The second (right) graph shows the development of cars bought by companies.

The Swedish government has also introduced a classification for cars that is called “supermiljöbil” or “super eco-car” which was also removed in 2022. A super eco-car is defined as a car that meets the EU emission requirements and doesn’t emit more than 50 grams of CO₂ per kilometer during mixed driving (Riksdagen, 2021). No gasoline or diesel cars have been classified as this in the data used for this analysis.

4.4 Income

The income of individuals used in this analysis is inflation-adjusted but reflects the income at the time the data was extracted from the vehicle registry. For example, if a vehicle record was extracted in 2015 and includes an ownership change from the year 2000, the associated income represents the individual's earnings in 2015, not in 2000. This introduces uncertainties on the income of individuals if the purchase occurred before 2014. As a result, the findings related to income in the earlier years should be interpreted with caution.

When splitting the consumers into four income groups, the difference depends on the individuals' economic conditions. The difference in vehicle mass was quite large at the

beginning of the period, see Figure 8, but this gap has shrunk to become less than half of the difference at the start of the 2000s. The largest difference in vehicle mass between the heaviest and lightest groups in the last year of data (2021) was about 40 kg or 3%, in the year 2000 the largest difference was about 106 kg or 8%. The largest difference in 2021 was between income group 4 and income group 2 and for the year 2000 it was between groups 4 and 1. The order in the final year from the lightest to heaviest was income group 2, group 1, group 3, and finally group 4.

1 st quartile	Up to 330,800 sek/year
2 nd quartile	330,800-526,100 sek/year
3 rd quartile	526,100-733,400 sek/year
4 th quartile	More than 733,400 sek/year

Table 6: Income quartile depending on the household's yearly disposable income.

When analyzing new car sales, the sample sizes are smaller resulting in larger confidence intervals in later years, but a trend can still be observed (Figure 21, Appendix B). The size of newly sold gasoline cars increased until around 2004 to then declined up until the middle of the 2010s to then start increasing rapidly again. From the sample sizes, it was also clear that consumers in the 4th income group bought the most amount of new cars for all years and that people in the 1st income group bought the least new cars for all years as can be seen in Figure 43 in Appendix B. This leads to individuals in income group 4 having a higher impact on which cars end up on the second-hand market. We can also see that consumers in income group 4 bought the biggest new cars. However, since the sample size decreased a lot in recent years the confidence interval of the groups has a lot of overlapping as can be seen in Figure 10. This leads to income group 4 having the biggest impact on the second-hand market. The second-hand market is gaining more large cars from income group 4 and increasing the number of large cars that the other income groups can purchase from the second-hand market. Which leads to an increasing mean mass of vehicles in all income groups.

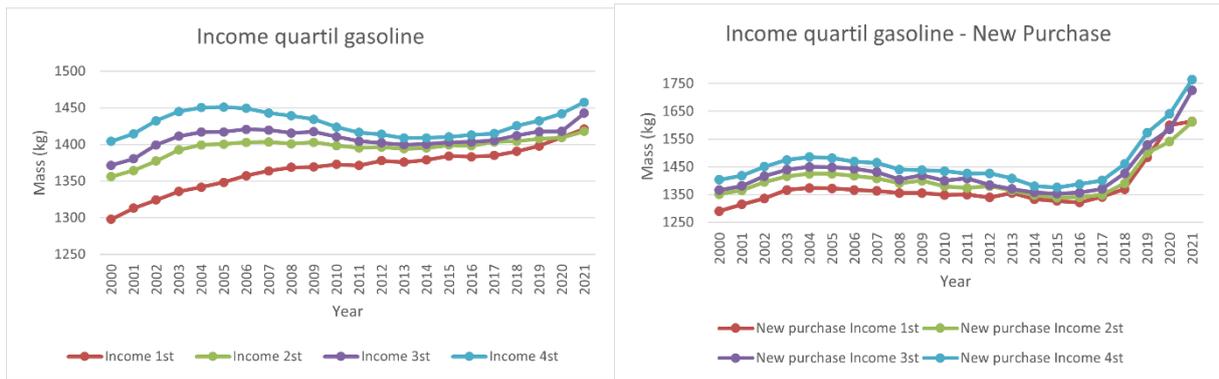


Figure 8: Mean vehicle mass development for ICEV gasoline cars when looking at income as a variable. The first (left) graph shows the development of all cars. The second (right) graph shows the development of newly sold cars.

The difference between the gasoline segment and the diesel segment is that diesel cars have a much smaller sample size and a much larger mean vehicle mass. The difference between income groups also seems to increase in the most recent years. In Figure 9 the trend can be seen. The ranking for the year 2021 here is group 1, group 2, group 3, and finally group 4. The largest difference in 2021 is between income quartile 4 and 1 and has a magnitude of about 146 kg or 9% while the difference in 2000 was only about 58 kg or 4%.

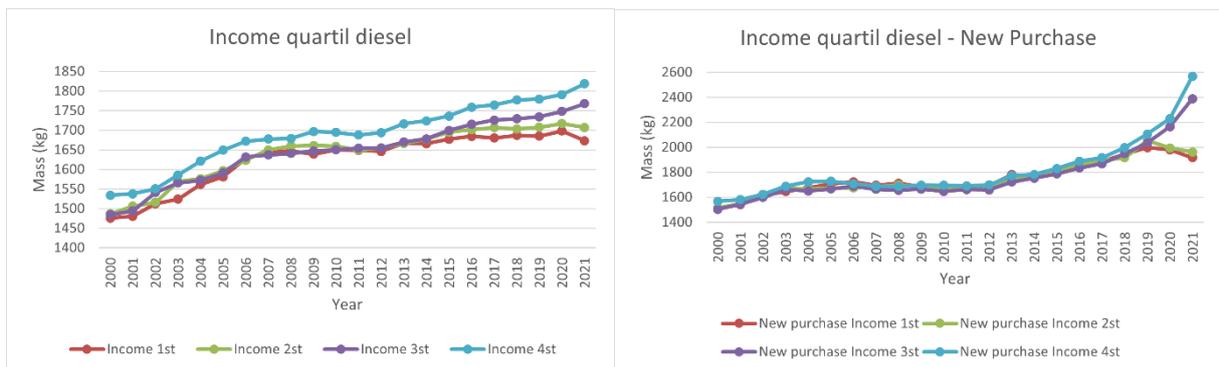


Figure 9: Mean vehicle mass development for ICEV diesel cars when looking at income as a variable. The first (left) graph shows the development of all cars. The second (right) graph shows the development of newly sold cars.

The difference for newly sold cars has also been quite small and has been since 2000. In the final years, a large difference can be seen with the largest difference being 650 kg, but the sample size is also very small, and the confidence interval is very large with major overlaps which can be seen in Figure 10. Income group 4 still purchases heavier cars on average, and they also purchase the most amount of new cars.



Figure 10: Confidence intervals for newly sold gasoline (left) and diesel (right) cars depending on income quartile.

4.5 Population Density

When studying the consumers' preferences shift depending on the population density of their place of residence, four groups were analyzed, ranging from urban living areas to rural living areas. In the case of gasoline cars, the difference between the groups is quite small during the whole period as can be seen in Figure 11. According to the statistics, a more urban lifestyle seems to result in a lighter car. The difference in vehicle mass between the rural category and the urban category in the year 2021 was around 38 kg. The ranking in 2021 was rural with the heaviest cars followed by exurban, suburban, and finally urban with the lightest cars. From the sample sizes, the share of the different categories in the total number of car buyers could be estimated, where the largest amount of car buyers lives in exurban areas (36 %) followed by people living in urban areas (30 %), suburban areas (19 %), and finally rural areas (16 %).

For new car sales, there is little difference between the categories. The general trend for how population density of the consumers' place of residence on vehicle mass is very similar to that of the income variable when looking at gasoline cars. Gasoline cars decreased in vehicle mass after 2004 to later on increasing again to reach new high levels.

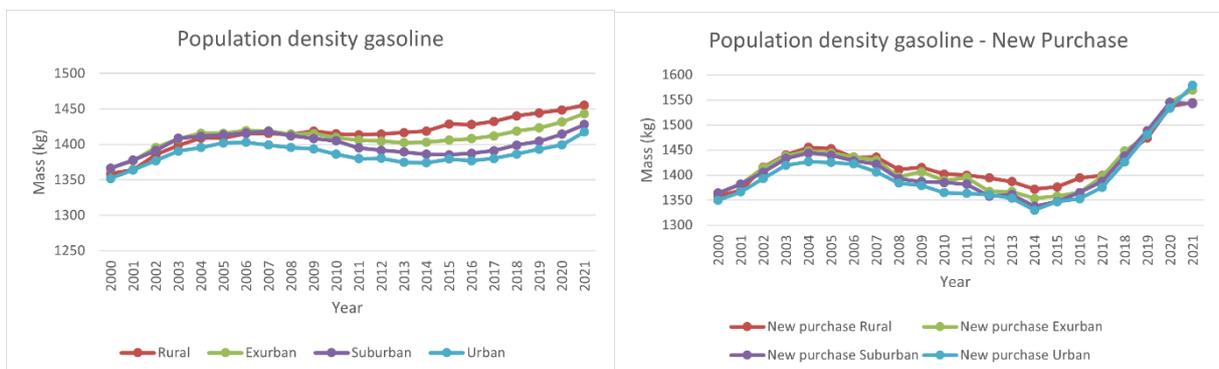


Figure 11: Mean vehicle mass development for ICEV gasoline cars when looking at population density as a variable. The first (left) graph shows the development of all cars. The second (right) graph shows the development of newly sold cars.

For diesel cars, the difference between the categories has stayed quite consistent with lower differences during the early 2010s as can be seen in Figure 12. The highest difference is 47 kg between rural and urban in 2021, while the difference in 2000 was 30 kg. The confidence intervals do, however overlap quite a lot, both for the years 2000 and 2020, therefore, it's not clear whether the difference between the groups is statistically significant according to Cumming & Finch (2005), but the trend towards heavier cars is clear.

For new car sales in the diesel segment, there has been no significant difference between the groups.

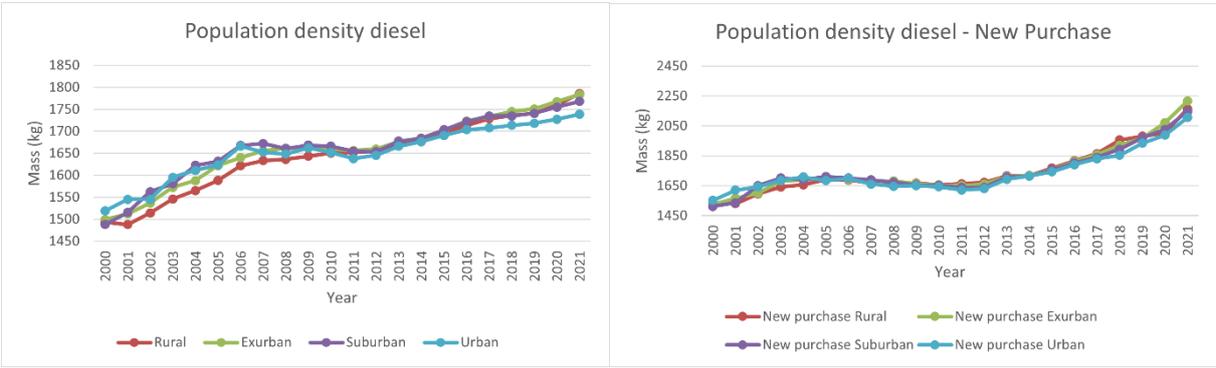


Figure 12: Mean vehicle mass development for ICEV diesel cars when looking at population density as a variable. The first (left) graph shows the development of all cars. The second (right) graph shows the development of newly sold cars.

4.6 Household Type

For the variable household type, the trend is similar for income levels. There was quite a difference in the beginning of the data, but that difference decreased and pretty much disappeared over time, see Figure 13. The highest difference is only about 27 kg. For the most part, the confidence intervals do imply this is true, only household with children over the age of 25 has large confidence intervals since these groups are quite small. The trend has generally been that cohabiting households have had larger cars than single households indicating that larger households have larger cars historically. Households in the cohabiting with children below the age of 25 category have the largest amount of cars followed by both singles without children and cohabiting without children categories. Cohabiting households have approximately 70 % of all cars and single households have 30 % of the private car fleet.

For new cars, the trend is again similar to previous variables, decreasing after 2004 and increasing after the middle of the 2010s. The households that purchase new cars are households either without children (singles without children and cohabiting without children) or cohabiting households with children below the age of 25. However, since the sample sizes

become a lot smaller for the last years due to lower sales to private individuals, the confidence intervals are quite large.

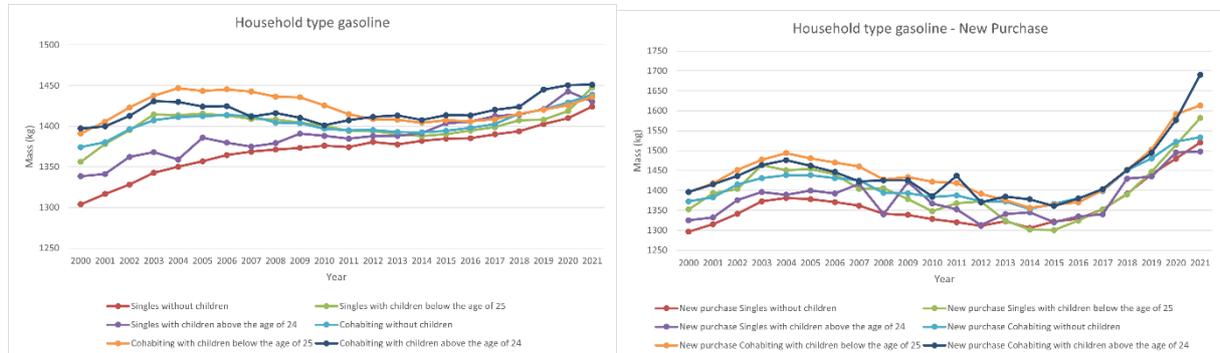


Figure 13: Mean vehicle mass development for ICEV gasoline cars when looking at the household type as a variable. The first (left) graph shows the development of all cars. The second (right) graph shows the development of newly sold cars.

For diesel cars no clear outliers can be seen in the result for the difference between household types in Figure 14, the general trend is that all households get increasingly bigger cars with the mean vehicle mass increasing no matter the household type. There are no clear outliers for new sales either, except a decrease in vehicle mass from 2004 and forward until the middle of 2010s. Cohabiting households have larger cars than single households that is clear even if the difference isn't that big.

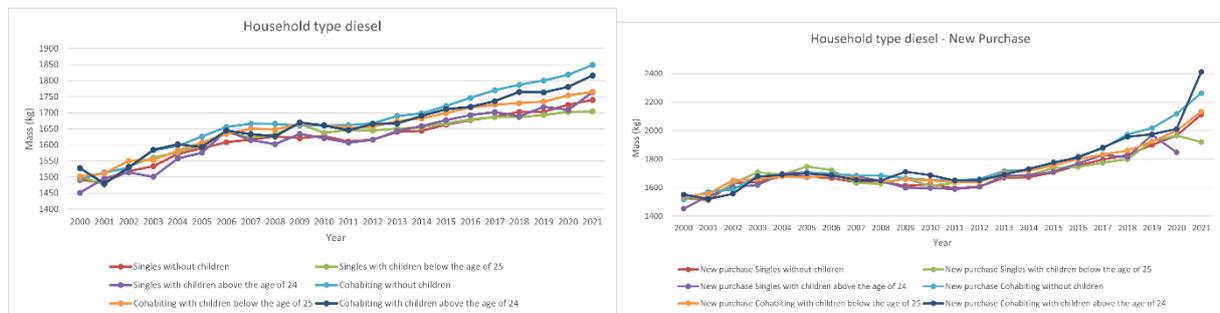


Figure 14: Mean vehicle mass development for ICEV diesel cars when looking at the household type as a variable. The first (left) graph shows the development of all cars. The second (right) graph shows the development of newly sold cars.

4.7 Housing Type

When considering how vehicle mass trends shift between consumers with different housing types, the trend has been quite stable. Generally, house owners have the heaviest cars and consumers living in apartments have the lightest cars. House owners also dominate the other housing types when it comes to who purchases the most cars. When splitting up the car ownership between the studied categories, house ownership has 59 % of the cars, apartment building rental property has 24 %, apartment building condominium has 13 % and both house

condominium and house rental have 2% of the total number of cars. The difference between the house ownership category and the apartment building rental property category was 65 kg in the year 2000 and in the year 2021 the difference is 49 kg instead, so the difference is shrinking but there is still a difference. The confidence interval doesn't overlap either between the apartment categories and the house ownership category. The other two categories of house condominium and rental do overlap since these groups are very small compared to the others. For new car sales it also becomes clear that house owners purchase new cars to a higher degree, and they are heavier than those bought by consumers living in apartments. Since house owners are the ones buying new cars, this dictates the ability of cars in the second-hand market, increasing the average vehicle mass.



Figure 15: Mean vehicle mass development for ICEV gasoline cars when looking at the housing type as a variable. The first (left) graph shows the development of all cars. The second (right) graph shows the development of newly sold cars. (Ab con = Apartment building condominium, Ab ren = Apartment building rental property, H own = House ownership, H con = House condominium, H ren = House rental property).

For diesel cars similar trends can be seen with house ownership generally resulting in the heaviest cars and apartment housing types resulting in a bit lighter car. The problem here with diesel cars is that the sample size becomes quite small for some of the categories. The house ownership category has 68 % of the cars, apartment building rental properties have 16 %, and apartment building condominiums have 12 %, the rest are around 1,5-2,0 % each. The smaller categories only include between 14,000 to 10,000 entries resulting in quite uncertain results for these categories, especially for the earlier years when the sample size was only around 50 cars per year in the smaller categories. However, the results for the apartment categories and the house ownership category have no overlapping confidence intervals in the later years, which suggests that they are statistically significant according to Cumming & Finch (2005).

Similar differences can be seen between house ownership, apartment building rental property, and apartment building condominium categories when analyzing new car sales, but housing ownership is overrepresented in the number of new cars being bought. In the trend for newly

sold cars, it can be seen in Figure 16 that the vehicle mass has started increasing quite a lot in the last couple of years but at the same time the number of diesel cars being sold diminished from just below 20,000 new diesel cars being sold per month to now less than 2000 per month (Trafik Analys, 2025).

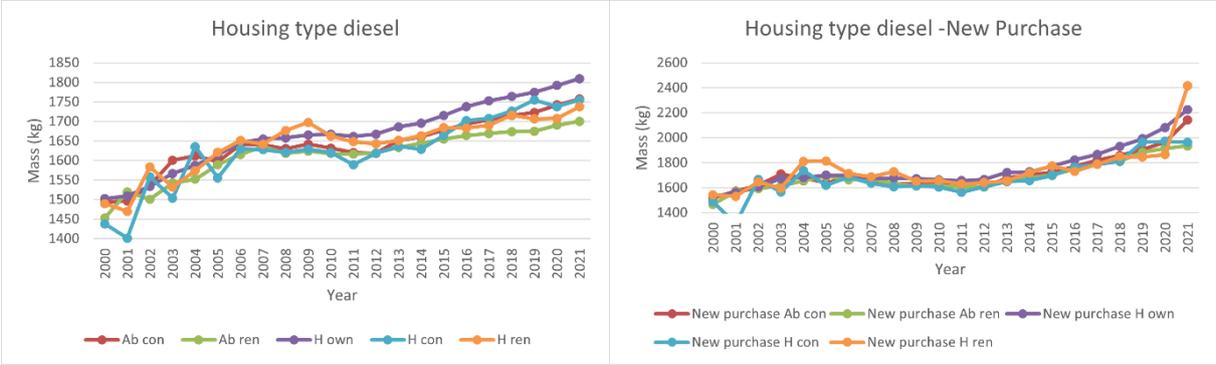


Figure 16: Mean vehicle mass development for ICEV diesel cars when looking at the housing type as a variable. The first (left) graph shows the development of all cars. The second (right) graph shows the development of newly sold cars. (Ab con = Apartment building condominium, Ab ren = Apartment building rental property, H own = House ownership, H con = House condominium, H ren = House rental property).

4.8 Gender

The gender of the car buyer has had quite a big impact historically on the vehicle mass for gasoline cars, as seen in Figure 17. At the beginning of the period, the difference between vehicle mass for cars bought by men and women was 131 kg or 10%, but in 2021, the difference was only 20 kg or 1,4%. The gender difference in vehicle mass between car buyers seems to have diminished in recent times. However, it became clear that there were a lot more men than women who purchase cars. 67 % of the individuals were men while 33 % were women in 2021.

For new car sales, the difference has also shrunk between men and women from 148 kg difference in 2000 to 99 kg in 2021. The percental difference on which purchase new cars is about the same here, with 64 % of new car buyers being men and 36 % of them being women.

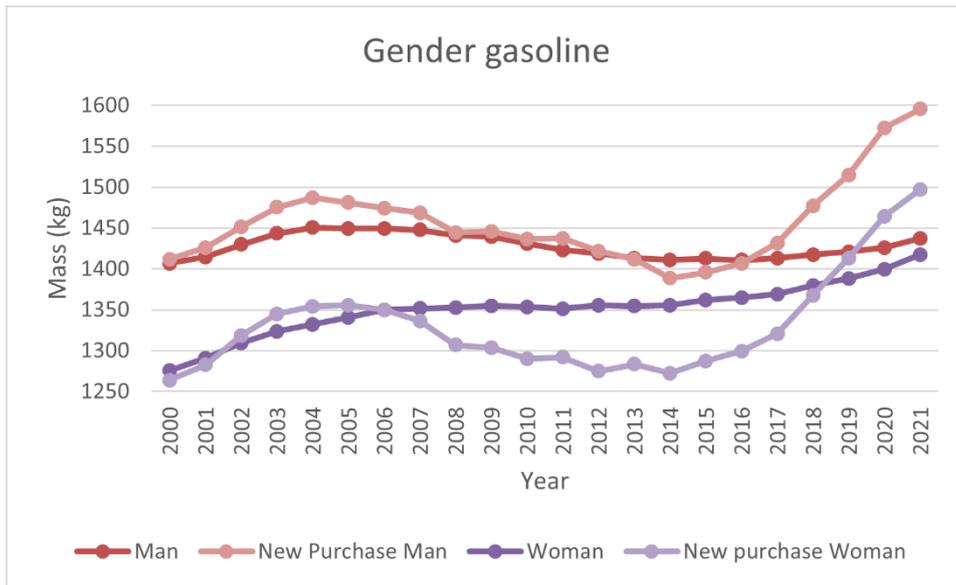


Figure 17: Mean vehicle mass development for ICEV gasoline cars when looking at gender as a variable for both the whole fleet and for newly sold cars.

For diesel cars, the difference has been lower between men and women, as seen in Figure 18. The difference in 2000 was around 50 kg in favor of men, and in 2021 the difference was around 14 kg in favor of men. Men purchase 73 % of the diesel cars while women purchase 27 % of the diesel cars.

For newly sold diesel cars the trend has been similar to the trend for all diesel cars, with low differences between men and women for all cars and newly bought cars. It also includes the period of time with stagnant increase where the trend stabilized for a number of years and then increased again. The percentage of men and women purchasing new diesel cars is very similar to the percentage of those who purchase diesel cars. 75 % of newly bought diesel cars are bought by men, and 25 % are bought by women in 2021.

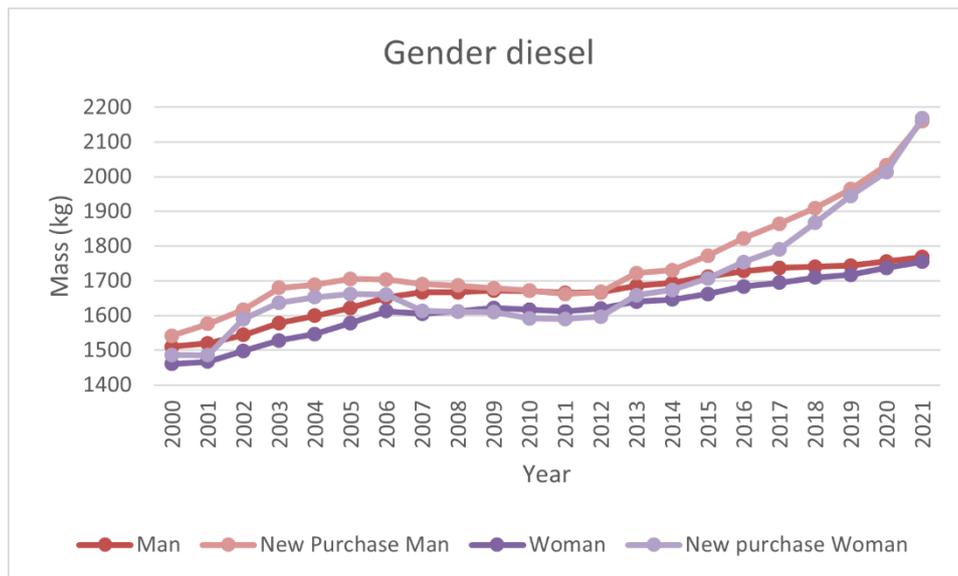


Figure 18: Mean vehicle mass development for ICEV diesel cars when looking at gender as a variable for both the whole fleet and for newly sold cars.

The confidence intervals with a level of 95% are also very small because of the large sample sizes with no overlapping of intervals, suggesting that these results are statistically significant for both years 2000 and 2021 according to Cumming & Finch (2005), see Figure 34 and 35 (Appendix B).

4.9 Age at Purchase

The age of an individual when purchasing a car seems to have had a higher impact previously. The age groups from 30 to 50 purchased the heaviest cars, most likely because of family situations and the need for bigger cars to fit the whole family as stated by Sovacool et al. (2018). This clear pattern seems to have disappeared in recent times. At the end of the period, the vehicle mass only increases with age, the older people get, the heavier and larger cars they get, but at the same time, the differences are comparatively small as can be seen in Figure 19. For the purchases in year 2021 the split on which age groups bought the cars is as follows age group <18 bought less than 1%, age group 18-30 bought 27 %, age group 30-40 bought 22 %, age group 40-50 bought 22 %, age group 50-60 bought 17 %, age group 60-70 bought 8 %, and age group >70 bought 4%. The age group below 18 and above 70 are not included since the sample sizes were quite small. The difference in 2000 between the heaviest and lightest age groups was around 75 kg (between age groups 30-40 and 60-70) and in 2021 the difference was around 22 kg (between age groups (60-70 and 18-30).

For new gasoline car sales 30- to 50-year-olds have generally purchased the heaviest new gasoline cars, and people older than that generally purchasing a bit lighter cars. This seems to have changed a bit over time but since the sample sizes of newly sold cars in recent years are

quite small, it is hard to clearly state if there has been a change. For the purchases of new cars in year 2021 the split on which age groups bought the cars is as follows age group <18 bought no new cars, age group 18-30 bought 14 %, age group 30-40 bought 17 %, age group 40-50 bought 18 %, age group 50-60 bought 19 %, age group 60-70 bought 17 %, and age group >70 bought 15%. Hence, people become more prone to purchasing new cars the older they get and that 50-60 year olds are the ones buying the highest amount of new cars.

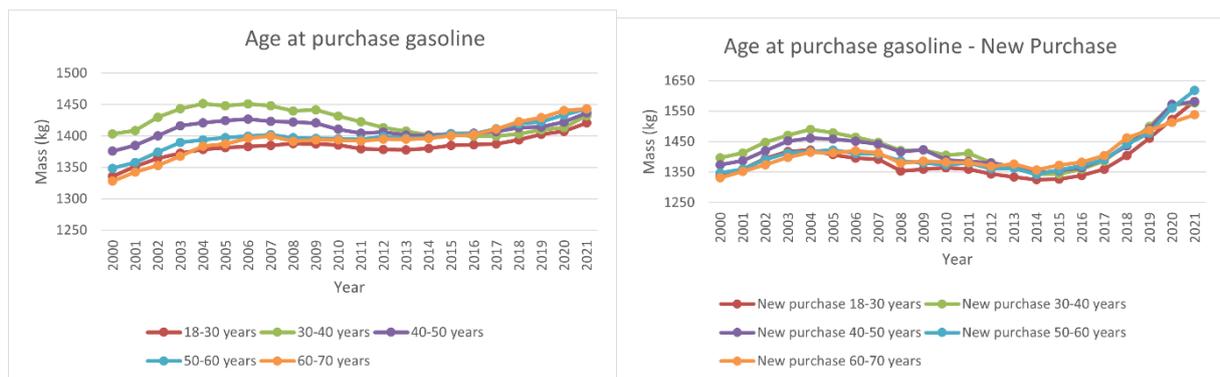


Figure 19: Mean vehicle mass development for ICEV gasoline cars when looking at the age at purchase as a variable. The first (left) graph shows the development of all cars. The second (right) graph shows the development of newly sold cars.

When analysing who purchase diesel cars between the groups, the percentage of which age groups bought the most amount of diesel cars in 2021 looks like this: age group 18-30 years bought 27 % of the cars, age group 30-40 bought 38 %, age group 40-50 bought 24 %, age group 50-60 bought 9 %, and age group 60-70 bought 9 %. Once again, age groups <18 and >70 are very small and will therefore be disregarded.

Age seems to have a larger effect on car size in recent years, see Figure 20, with 60-70 year olds purchasing the heavier cars in the diesel segment. The confidence intervals of 95% do not overlap, which suggests that this is statistically significant according to Cumming & Finch (2005).

When it comes to new diesel car sales a similar trend can be seen with larger differences between younger and older age groups. Age groups 18-40 can be seen purchasing lighter cars than the older age groups, but there are also fewer cars being purchased by these age groups. The split on which age groups purchase new diesel cars is as follows age group 18-30 years bought 12 % of the new diesel cars, age group 30-40 bought 18 %, age group 40-50 bought 18 %, age group 50-60 bought 23 %, age group 60-70 bought 19 %, and age group >70 bought 9 %. Once again the possibility of purchasing new cars rises with age, in this case, the age group of 40-50 years are the ones purchasing most of the new diesel cars.

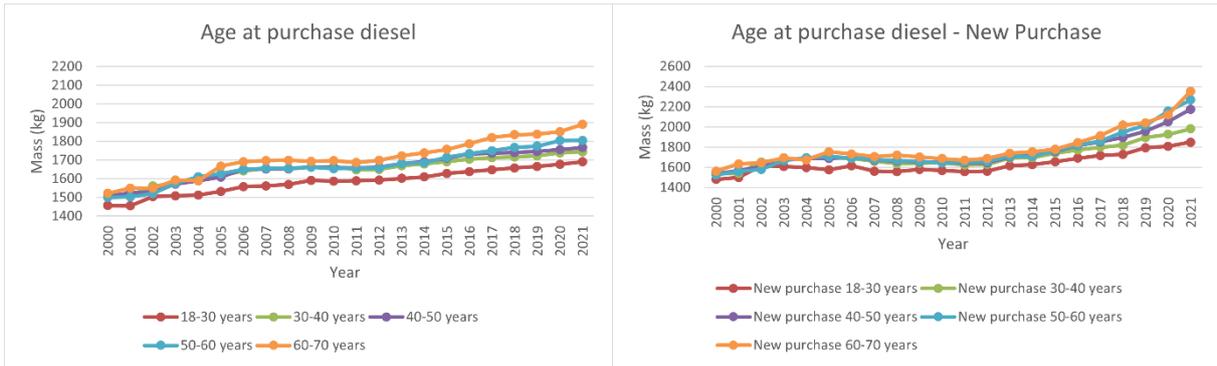


Figure 20: Mean vehicle mass development for ICEV diesel cars when looking at the age at purchase as a variable. The first (left) graph shows the development of all cars. The second (right) graph shows the development of newly sold cars.

5 Findings from Expert Interviews

The way that consumers choose to purchase cars is influenced by multiple factors. These factors include economic factors such as purchase price, fuel price, and subsidies, functional needs such as the need for more passenger space or cargo space, safety for the driver and passengers, market trends which dictate which cars are available on the market, and policy measures that could promote a certain type of car. Semi-structured interviews were conducted with experts in the automotive industry, NGOs, governmental agencies, and academia. All interviewed experts agree that the current trend in vehicle size is towards larger and heavier cars, and that the trend is driven by both consumer demand and automotive industry strategies. At the same time, there are opportunities to shift the trends towards smaller cars by utilizing targeted policy instruments and incentives. All experts agree that without political intervention, the trend towards larger cars will most likely continue due to current economic incentives for benefit cars, consumers' preferences for larger cars, and industry priorities on making both a profit and speeding up the electrification process. While some experts point out that shifts towards smaller vehicles are being observed in emerging market segments, all experts agree that strong policy measures are needed for the trend to shift for passenger cars in general. Such policy measures include introducing incentives for smaller cars, adjusting benefit car taxation, and implementing EU-level instruments to limit the maximum weight a car can have in order to drive change. According to Carl-Erik Stjernvall at Riksförbundet M Sverige the Swedish government has historically influenced which cars consumers have purchased through policies. If the Swedish government wants the trend to change, then this may be needed again to promote downsizing and ensure a more sustainable and efficient car fleet.

5.1 Consumer Preferences

Most experts agree that economic factors have the biggest effect on which cars consumers decide to buy. Mikael Levin at Transport Analysis stated that when looking at new car sales, it is on average people around the age of 55 that purchase new cars, or there are companies that buy them and use them as benefit cars. When looking at cars that are leased instead, they are leased by people with generally lower incomes and ages of 40 or below, and they mostly lease cars that are, on average, smaller and lighter than the cars that people buy. The group that can buy a new car is a privileged group of wealthy people who can then perhaps afford to buy more or bigger cars than they had intended or needed. Thus, the inflow of new cars is

very much connected to people with high incomes, and people with higher incomes are more inclined to spend more to gain the extra benefits that a car can bring them. On top of that, the benefit car system in Sweden (explained in Box 5.1) is very generous. Usually, the people who have access to benefit cars are also the ones who have the highest income. Since benefit cars are subsidized by having to pay less tax than if the car had been owned privately, this leads to a higher demand for more premium cars since they become cheaper to own, which leads to a higher turnover of new benefit cars. And it is these cars that eventually become available on the secondhand market for purchases by people with lower incomes. This can lead to a problem in the future since there is a demand for smaller secondhand cars among people with lower income, but there are no incentives to promote smaller cars at the moment. However, if a fast electrification of the car fleet is desired, the benefit car system could speed up that process due to its high turnover. Since the goal to reduce emissions by 70% by 2030 is only measured at the tailpipe, the whole lifecycle emissions may be disregarded which can lead to an overfocus on electrification and a sub-optimized system. The goal may then become to electrify as fast as possible while ignoring the emissions and energy use during production.

A benefit car can be used privately by the employee but is owned or leased by the employer. It is considered a taxable benefit and is taxed based on the cars price any additional equipment, vehicle tax and whether the car is environmentally friendly. If the car is used privately for more than 1,000 km or on more than 10 occasions per year, it must be taxed as a benefit. Fuel and congestion tax paid by the employer are taxed separately. The benefit is valued according to a standard and added to the salary when calculating tax. (Skatteverket, 2025)

Box 5.1: Explanation of the benefit car system.

Functional needs are also highlighted by many of the experts as reasons for people demanding larger cars. When families become larger, there is a larger need for cars that can fit the whole family. With larger families, there is also a need for larger cargo space to fit a pram and luggage. People may need to have the possibility to connect heavy trailers or animal transport, which could require larger, more powerful cars. People living in rural areas may have difficulties driving during the winters with smaller cars. Elderly and disabled people may have difficulties getting into smaller cars and may therefore benefit from owning a car with high ground clearance, such as an SUV, for example. Many experts also expect, and admit from personal experience, that people plan their car purchases based on the occasional

vacation. Likely reasons stated by the experts include that carpools are rare and hard to plan into people's schedules, and the comfort of not having to rent a car just for the vacation, even though it would be generally cheaper than owning a car. People do not want a car that works 9 out of 10 times, but rather a car that works for all occasions. This is likely a reason for people driving cars that are too big for most of their needs. The same is true for the range of EVs. Even though people often drive 30-40 km per day, they still want a range of 500 km for those occasions when that is needed, as stated in the interviews.

The experts also indicate that safety and comfort are seen as a prominent factor. Larger cars are considered safer by the consumer since they are safer for the person inside a larger car. Therefore, people are willing to pay extra for the safety that a larger car can bring them. Drivers want others to drive cars that prioritize general safety for the transport system, while their own car should prioritize their own safety. The experts speculated that people seem to own larger cars in cases when safety is considered more important, for example, when having children. However, as found in the literature (Thomas & Walton, 2008), some experts pointed out that with a growing share of large cars, the general traffic safety declines both for drivers of large and small cars. At the same time, the traffic safety standards have become much higher today due to new safety systems, which also increase the size of cars, as stated in the interviews. Nevertheless, people buy SUVs to feel safe, they sit higher up and feel safer for it.

The SUV market segment also has a larger focus on space and comfort for the drivers. The comfort that comes with a larger car is something that a lot of people are willing to pay for and that they are not as willing to compromise with. From the interview with Volvo, the representative showed a report that concluded that when people get a smaller budget, they first and foremost choose to keep their car for a longer time before getting a new car, followed by buying a used car from the secondhand market, switching to a cheaper brand of car, buying a cheaper car and considering other transportation options. Buying a smaller car is not one of the first choices. If you need a big car, you can't buy a smaller car since it won't fit your needs. It can also be difficult to switch to a smaller car if the consumer has had a larger car in the past and has become accustomed to its benefits. People indulge themselves with a large car that has lots of luggage space and comfort.

Many of the interviewees also mentioned the status of cars and loyalty towards brands as impactful factors in consumers' preferences, but this factor may have become less important now than before. For some people, a car can have a high importance in the form of status and by owning a large car, people can show others that they have succeeded in life and that they

are doing well. Even though SUVs are one of the most common car types now there could still be a status effect. By not owning a large car it could show that you are not so well off if you buy a smaller car. This status effect is a decreasing factor, but there is still a fairly large segment that sees it as an important status symbol, according to some of the experts. This is true for brand loyalty as well. Brand loyalty was more common previously, especially when SAAB was still around, but this effect also seems to have decreased in recent times.

The automotive industry strategies also affect which cars consumers prefer to buy. As the industry focuses on electrification, increasing safety, and adding other comfort functions in the cars this will increase the vehicle mass and likely size as well to fit everything in the cars as stated by the representative for Riksförbundet M Sverige. Vehicle manufacturers have needed to bring BEVs to the market to achieve EU emission requirements and have therefore focused on premium vehicles since they will have an easier time selling expensive BEVs within that segment. Consumers within the premium or luxury segments are less price sensitive, which is the reason for focusing on these segments. It is also easier to build a car on a large platform, as it becomes easier to fit everything that is needed inside the car. The car market will also be heavily affected by domestic car manufacturing. In Sweden, Volvo has a large part of the market, and since Volvo currently doesn't manufacture any small models, this is likely to have contributed to Sweden having the largest cars on average in the EU. Volvo has a large range of SUVs, and they are not the only manufacturer with this focus. The reason for the focus on SUVs is that the SUV concept is easy to sell, many people think that the SUV stands for something. It is also more profitable for manufacturers to sell larger cars. It is more difficult to achieve profitability in small cars, especially in the premium segment.

There are also no incentives for people to buy smaller cars. The Swedish government has removed policy instruments on the private side but left them on the company car side in the form of the benefit car taxation. If you have a perspective on justice, you might wonder why people with company cars should be able to access cheaper cars than private individuals. Earlier there was a bonus-malus system that punished vehicle owners with high emissions and rewarded owners of cars with low emissions, but since 2022 the bonus was removed. Hence, people are currently only being punished for purchasing cars with high emissions in the form of extra taxes. Riksförbundet M Sverige stated that Sweden has had some form of control for so many years that there has almost always been a tax reduction or a benefit for something. Some examples of this are ethanol in the 00s, then a limit on carbon dioxide that resulted in a shift towards diesel cars in the 2010s before the scandal and the switch to giving bonuses to

electric cars. Since the government took the BEV bonus back, new car buyers are now a bit more at a loss as to what to choose. There is no discount or direction that makes consumers know which car they should buy, which is different from before. As fuel prices have become lower and there are no subsidies, individual consumers are choosing electric cars to a lesser extent and small petrol cars to a greater extent. The cars that private owners choose are different from those of company car owners. This will of course have consequences in the future when few smaller cars will be available on the second-hand market.

5.2 Trends in the Market

The current trend within the transport sector is an increase in available BEV models and this has led to an increase in vehicle mass for newly sold cars. However, even when analyzing other car types, like gasoline and diesel, the vehicle mass and size are also increasing (Section 4). The main reason for this trend is that there are so many new things that should fit inside cars now. Examples of this are comfort features, engine and transmission, exhaust system with cleaning functions, larger fuel tank, and safety features. A certain width is also required in the car to protect against side collisions, according to Carl-Erik Stjernvall at Riksförbundet M Sverige. Safety and emission requirements are making cars increasingly expensive and heavier. The vehicle mass is only increasing while at the same time companies are trying to develop new materials and more energy-dense batteries. According to Lars Malmek at Volvo it is the range of cars that drives the development towards heavier and larger cars.

At Transport Analysis, they are now seeing an expanded model range of smaller and cheaper electric cars. Privately leased cars will continue to be lighter cars. As for the other larger electric cars to become lighter, it is about battery technology, so that lighter batteries can be built and thus reduce the vehicle mass. They also believe that gasoline and diesel cars will not become lighter, partly because they have problems with purification technology and limited technological development. Diesel cars are basically adapted as a form of special vehicle now. Staffan Algers also believes that additional models of cars in smaller segments will eventually come out on the market to satisfy those consumer segments. And at Trafikverket, they can also see that there are a lot of small vehicles, such as microcars, that have become available on the market.

The view on the future development of the transport sector differs a bit among experts. Some are more optimistic, and some are more pessimistic about the future. Some highlight the development of lightweight materials and development in battery technology, which would

result in lighter cars but it is unclear by how much. Range anxiety could also be handled in other ways than increasing range capacity, for example, being able to switch batteries fast when there is a need for additional range instead of having to stop and charge the battery. This is currently very hard to do since there is no one-size-fits-all battery type, and therefore not possible.

Most experts agree that no change to the trend will occur if there is no pressure from policymakers. Swedish Society for Nature Conservation stated that if nothing is done politically, the trend will probably move towards more SUVs and that, political control is required to enforce energy efficiency and smaller batteries.

“If you want to bring about change, it has to happen from a political perspective. Companies are very slow to adapt: it is only when they are faced with a threat that they implement change” Lars Malmek, Volvo Cars.

If car manufacturers don't get an incentive to change their ways, they won't change and risk losing market share to other brands. For companies, it comes down to profitability and if they can't see a business case that they can profit from, they won't change it.

“There is nothing in the market that tells us that it feels like a trend is blowing and that people will choose smaller cars here now, rather the opposite in fact” Lars Malmek, Volvo Cars.

Many suggestions were put forward for different potential policy interventions during the interviews. One suggestion was to return to having a weight-based tax instead of an emission-based tax since most cars already have very low emissions compared to before and BEVs will have no emissions and therefore a very low tax. Going back to a weight-based tax could incentivise consumers to choose smaller cars. The drawback however is that this will likely have low acceptance among consumers, and could also hinder the electrification process, according to Mikael Levin at Transport Analysis. Such a policy intervention could of course include exceptions for BEVs but that would complicate its design.

Other ways to achieve change include incentivizing smaller cars in different ways. Suggestions included having a ceiling on a bonus-malus system to not promote larger cars too much, lower parking fees for smaller cars, lower congestion fees for smaller cars, changing the generous tax-benefits through the benefit car system, and banning large and heavy cars in city centres. Some of these will likely have a large effect, especially changing tax on benefit

cars and having a ceiling on a bonus-malus system, which would directly change how economically beneficial larger cars can be for people. It is less certain how big an effect changes on parking fees, congestion fees and banning larger cars from city centres will have. These fees and restrictions won't affect everyone either, they will mainly affect people living near larger cities, while people living in more rural areas won't be as affected. If change is desired for the whole car fleet and not just near cities, then these changes may not be the most effective ones. Still, they could be beneficial in cities where congestion, local air pollution, and space are considered problems. Suggestions also included instruments at EU level to limit the mass of cars, and push for more energy-efficient cars in a similar fashion to the adopted emission limits, which gave the auto industry a boost.

Some experts also expressed thoughts that policymakers might not see large cars as a problem. policymakers have had a larger focus on limiting emissions through taxes and promoting the electrification process. The size of cars has been ignored despite its impact on the environment and road safety. Helen Lindblom from Trafikverket suggests that instead of influencing car buyers focus on influencing EU legislation around supply chains to make these supply chains more sustainable. A problem with the extraction of materials outside the EU in countries with poor control is that environmental problems can occur and are currently not represented in the price of those materials. Hence, it would be better to influence sustainability standards to achieve sustainable supply chains than to limit the materials.

5.3 Possibilities and Barriers

Possibilities that might enable vehicle downsizing include the EU emissions trading system (ETS), which will reduce emissions from material and electricity production in the EU. To reduce greenhouse gases, there are strong instruments at the EU level in the form of restrictions on which cars can be sold and emissions trading that is strongly binding and goes towards zero. Helen Lindblom from Trafikverket believes there will be price signals that will lead to smaller vehicles, but she is unsure how long it will take. If small cars become cheaper, perhaps consumers will be more motivated to get a smaller second car. The prospect of self-driving cars may also lead to large amounts of energy and material savings. In a study that Staffan Algers was involved in, they found that only 10% of the vehicle fleet was needed to fulfill the same transport work as regular privately owned cars. At the same time, producers want consumers to continue to own private cars that are self-driving but as a driver assistance system instead of there being public car fleets that are self-driving, to ensure continued

profits. Self-driving cars may also be difficult to implement in all environments, possibly difficult in northern Sweden with a lot of snow for example. Another possibility is if it becomes too expensive and too troublesome to own a larger car, to promote people to choose a smaller car because they are cheaper and easier to maneuver, but for this to happen policy instruments are needed.

Barriers to vehicle downsizing include the fact that there are no incentives for consumers to change their purchasing behavior towards smaller cars. It's a big investment from the start to purchase a car, and a car is a very functional investment. It may feel strange for consumers to spend half a million SEK on something they didn't exactly want. People generally don't choose things for the sake of the environment. It is not up to individuals to deal with environmental issues, it should go up to a higher level, preferably a global level, is the opinion of Jan-Erik Swärth at VTI. The people who have a need for a large ICEV must be able to feel that they can get such a car. The size of the car is highly dependent on the size of the household, and that variable can't really be influenced. If consumers are going to choose a smaller car, they probably want some other feature that is better, perhaps that they are cheaper, more fun to drive or have other features that improve the experience. The argument of habit can be tangible and make changes slower. Brand loyalty can also be an important part of why consumers do not change their habits that much. It is also more comfortable with larger cars with plenty of seating space and more modern features. People who have problems with their knees and hips may need a car with higher ground clearance to be able to get in and out of the car. Many people find it practical to have a SUV, for example, easier with child safety seats, and the traffic safety perception that small cars are seen as less safe may be difficult to change. It's difficult to justify the argument of choosing a smaller car so you don't risk killing someone else, you'd probably rather choose a larger car to protect yourself.

5.4 Pros and Cons

Finally, all interviewees were asked about their views on the pros and cons of vehicle downsizing. The positive aspects of vehicle downsizing of cars that they came up with are the following:

- The existing railings along roads cannot handle heavier cars, therefore it would be beneficial if cars became lighter otherwise all railings need to be reinforced so they can manage the larger cars.

- If cars become smaller, they should probably become cheaper as well which would leave people with more money, but if that is good from an environmental point of view is hard to say. It could lead to more emissions in other areas.
- Lighter cars could lead to cleaner air with fewer particles but only minimally, the problem that creates particles is mainly heavy trucks and studded tires. Studded tires are necessary from a safety point of view.
- In traffic accidents involving SUVs, there is a much higher fatality rate, if all cars became lighter it could lead to lower fatality rates in traffic accidents.
- A greater variety in the car fleet can create greater benefits for more different customer groups in the second-hand market where there is a higher demand for smaller cars. If everyone buys big cars today, there won't be any smaller cars on the second-hand market in the future.
- There is less material consumption, less energy need, and overall lower climate impact. As long as cars get smaller and there is still the same number of cars in the car fleet this would bring positive environmental improvements. And if less material is needed this would possibly result in less impact on people working in mines and factories.
- Less barrier effects and less surface area taken up by cars. This would reduce the need for large parking spaces and the space that is saved could be used for other purposes.
- A larger car leads to more costs in the form of tax if they emit CO₂, insurance, wear and tear, service, tires, and repairs. All costs would be reduced, they would also be more energy efficient, reducing costs there as well.

The negative aspects for consumers, society, and manufacturers that the experts came up with are the following:

- Downsizing of cars may hinder electrification, therefore BEVs may need to be allowed to be heavier for the moment.
- If you take away people's ability to move, then social costs such as healthcare and crime will increase. Don't restrict people's mobility, as this will lead to other societal problems. Restricting mobility may greatly hinder elderly and disabled people from accessing their needs.

- Producers have to sacrifice things that consumers value, such as space and comfort. As long as it applies to all producers, it is the producer who can make the change least noticeable who benefits the most.
- Smaller and cheaper vehicles may lead to consumers purchasing more cars so that a household may own two or three cars instead of one or two which would lead to more material consumption. This could, however, probably be regulated through other means such as vehicle tax, congestion fees or parking fees.
- There is a kind of unique phenomenon in Sweden that has probably led to slightly larger cars and that is the moose. The mass of a moose is at a very unfavorable height and there is a high risk of serious injury or death. A smaller car would result in a worse crash for the people inside the car than if the car was of a larger model.
- Commercially, there are disadvantages and that is one of the reasons why Volvo has hesitated to make smaller cars. Firstly, it is difficult to fit all the safety features into small cars and, secondly, it is more difficult to achieve profitability in small cars, especially in the premium segment.
- A small car may start to compete with other means of transportation.

Some of the points they brought up could be seen as both positive and negative, or a rebound effect, an example of that is if people had more money left over, then this could lead to them causing emissions in other places instead. That is a possibility but at the same time, it is hard to predict where this would lead.

6 Assessing the Impact on Specific Energy Use

The variables that were tested in the specific energy use modeling were the mass of the cars and the frontal area of the cars. The way it was tested was by varying the vehicle mass and frontal size separately at first to see the impact these variables have. Both the mass and the frontal size were tested with base values and with a 10% increase and decrease down to 50% of the base value and up to 150% of the base value. The values that the model gave for these runs are shown in the table below.

MASS	BEV	ICEV-g	ICEV-d
50% of base case	159 Wh/km	619 Wh/km	575 Wh/km
Base case	217 Wh/km	893 Wh/km	875 Wh/km
150% of base case	275 Wh/km	1173 Wh/km	1181 Wh/km
Percental change	±27%	±31%	±35%
FRONTAL SIZE	BEV	ICEV-g	ICEV-d
50% of base case	167 Wh/km	728 Wh/km	745 Wh/km
Base case	217 Wh/km	893 Wh/km	875 Wh/km
150% of base case	267 Wh/km	1064 Wh/km	1011 Wh/km
Percental change	±23%	±19%	±16%

Table 7: Results from the specific energy use model for different scenarios.

Both the mass and the frontal area have linear relationships to the specific energy use. This is clear from mass only being included in Equations 1 and 3, and the other parameters in these calculations are the same for all test cycles. Since mass is only multiplied the relationship becomes linear. The same is true for the frontal area, which is only included in Equation 2 through multiplication, which again makes it linear since no other parameters are changed between test cycles. Therefore, a linear regression analysis can be applied to the data to quantify the relationship between mass and frontal area and the specific energy use. The equations gained are stated in Table 8. Graphs showing the linear regression can be found in Appendix C.

Mass as variable	
BEV	$y=0.061x + 100.65$
ICEV-g	$y=0.356x + 229.57$
ICEV-d	$y=0.291x + 269.66$
Frontal area as variable	
BEV	$y=0.436z + 116.53$
ICEV-g	$y=1.461z + 557.96$
ICEV-d	$y=1.158z + 609.76$

Table 8: Results from linear regression testing for each car type and variable, with x representing the vehicle mass in kg, and z representing the frontal area in dm^2 .

These results show that both gasoline and diesel cars are affected more by these changes than the BEVs indicating that BEVs are more efficient than ICEVs and that the downsizing of ICEVs will have a bigger effect than the downsizing of BEVs. According to this result each kilogram that is reduced would also reduce the specific energy use by 61 mWh/km for BEVs and for each square decimeter less frontal area the reduction would be 0.436 Wh/km, however reducing the frontal area by that much would likely be very difficult. These results are also based on the assumption that each variable is tested in isolation, when mass is tested the frontal area isn't changed and vice versa. No efficiencies or coefficients are affected either, which would likely not be the case in real-world conditions. Li et al (2019), compared 34 BEV models on the Chinese market to identify the relationship between mass and specific energy use. They found, through linear regression, the relationship $y = 0.051x + 60.576$ [Wh/km]. Their results are similar to the results from the specific energy use model, but differ in both the inclination and the constant. The reason for the difference is likely since in reality there are more variables that change than just vehicle mass or frontal area on their own. It is also unclear if they have used the WLTC. The result might differ if using another test cycle.

Kremzow-Tennie et al (2021), compared the specific energy use of a BMW i3 and a Tesla Model S when they were either 100 kg heavier or 100 kg lighter. What they found was a decrease of approximately 4 Wh/km for both the BMW i3 and the Tesla Model S, which translates to 0.04 Wh/km per kilogram. The percentage of specific energy use decrease for the BMW i3 was 2.99 % for 100 kg and for the Tesla Model S it was 2.69% for 100 kg. When comparing this with the result from the specific energy use model developed in this report, a decrease of 100 kg resulted in a 2.62% decrease in specific energy use. This indicates that the result from the specific energy use model is possible.

Green NCAP (2023) have looked into what impact size has on specific energy use and the environment. They tested 34 different cars with different powertrains, and they have found that no matter which powertrain, if the car mass increases by 100 kg, then the specific energy

use rises by about 2 %. This result is close to what Kremzow-Tennie et al (2021) found as well. Green NCAP (2023) also found that a net increase of 100 kg could result in an additional 500-650 kg of greenhouse gas emissions and 1.9-2.4 MWh of energy demand during vehicle production. This is while not including battery production, but including recycling of car parts.

6.1 Impact of Vehicle Size on Energy and Resource Demand

Confederation of Swedish Enterprise published an analysis of the transport sector, where the authors explore the sector's future energy use (Agering et al., 2024). The authors found that in 2022 road traffic accounted for energy use of 73 TWh, mostly petrol and diesel. To achieve the climate goals that the Swedish government has set by 2045, their goal is to transition to renewable fuels in which electrification of vehicles is included. They also created three scenario models for the future: high, low, and medium electrification. Their models had an electrification rate for the whole fleet of 68%, 71%, and 77% for low, medium, and high, respectively, and energy demand for passenger cars of 10.5, 10.9, and 11.9 TWh respectively. When accounting for all road traffic including trucks and buses the energy demand becomes around 15.2-18.3 TWh. This may however vary depending on the efficiency of the cars that are being used.

Weiss et al (2024) found that an increase in vehicle mass by 100 kg increased the specific energy use by 0.17 ± 0.05 kWh/100km and that each doubling in mass increased specific energy use by 18-30 %. They also explored the impact of the vehicle's frontal area on specific energy use and found that an increase in frontal area of 1 m^2 resulted in increased specific energy use of 9.2 ± 0.5 kWh/100km. However, they also found that increasing the driving range by 100 km had a negative correlation with specific energy use. By increasing the driving range, the specific energy use decrease by 0.88 ± 0.16 kWh/100km, and each doubling in drive range decreased specific energy use by around 9 to 15 %. This could be seen as counterintuitive but can be explained by the authors assuming increased energy density in BEV batteries. From the result, they found this suggests that the development in improving batteries energy density has been dominant, meaning that instead of just adding larger batteries the batteries also become more efficient leading to lower specific energy use. From these findings, it becomes clear that vehicle mass and frontal size both affect specific energy use and that focusing on improving battery energy density would be beneficial in decreasing specific energy use. This is a very optimistic approach. Morfeldt et al (2025) found

that by 2030, the material need for batteries could be reduced by 14-16%, and by 2050, this reduction could be as high as 36-42%. This would lead to lower emissions during the production of batteries and cars and lighter cars. This would not only affect the battery size but also the specific energy used since the car would become lighter. It is therefore important to separate correlation and cause. If the development of battery energy density were to start to stagnate, then the longer range requirements risk leading to higher specific energy use, which could lower the climate benefits that BEVs bring. The connection between the mass and the specific energy use is vital here. Heavier cars require more energy to accelerate and brake, especially within cities with a lot of stops and starts. The frontal area is also important, especially during travel on highways with high speeds. For these reasons, both factors are important when analysing the energy performance of a car.

The size of the car also affects the materials needed and by extension the emissions created during the lifecycle of the car. According to Gröna Mobilister (2023), it is currently not possible to compare the climate impacts of the production phase of different producers since there is no standardized method to conduct life cycle assessment (LCA). Such a standard is planned to be introduced at the end of 2025. It is however possible to compare cars from the same producer. They acquired LCAs for small cars and big cars and compared the results. They found that the percental difference between a small car and a big car was bigger for EVs. A normal-sized BEV in the VW Golf class had an impact during manufacturing and scrapping of 11.6 tons CO_{2e} while a big SUV had an impact of 18.4 tons CO_{2e}. This is an increase of about 59% while an ICEV had an increase from 7.2 tons CO₂ to 10.5 tons CO₂, which in percentage is 56%. While in the use phase, the ICEVs have much higher emissions than EVs. At the same time, people seem to acquire larger cars than they need. In 2011 only 4% of Swedish households had five or more persons in their households (Kågesson, P. 2011), but still cars get larger. This leads to consumers driving around in larger cars than they need and more emissions during the whole lifetime of the car.

6.2 Other Methods for Vehicle Mass Reduction

There are more ways of reducing the vehicle mass and reducing fuel consumption and impact on the environment without compromising the comfort of passengers. Two ways of accomplishing this include topology optimization and material substitution (Chirinda et al. 2024). Topology optimization is based on efficient design processes to optimize the usage of raw materials and create conceptual structures, however, the resulting structures are often too

complex for traditional manufacturing processes, therefore additive manufacturing could be a solution (Czerwinski, F. 2021). Additive manufacturing is a concept of lightweighting through topology optimization, the structures can be made lighter by making the structure hollow but with high strength and stiffness. Material substitution is a method of changing materials to other lighter materials where it is possible. Both methods can be summed up under the lightweighting concept (Chirinda et al. 2024). There is no best option to reduce vehicle mass out of these two. Combining them can greatly reduce the mass of the vehicle, and reduce carbon emission while at the same time retaining the performance and safety of the vehicle.

The effect of lightweighting can be seen in the ICEVs fuel economy and in BEVs increased range (Czerwinski, F. 2021). For ICEVs, a mass reduction of 10% resulted in reduced fuel consumption by 6-8%. For EVs, a mass reduction of 10% resulted in an increased range of around 13.7%, assuming constant battery capacity. The expected vehicle mass reduction by 2035 is 20-25% for ICEVs, 20-30% for BEVs (Czerwinski, F. 2021), and, by 2045, the vehicle mass reduction levels are expected to reach up to 48 % (Ehsan et al, 2018).

Materials that can substitute conventional materials like steel and cast iron are needed to accomplish lightweighting. These materials can be grouped into four categories: light alloys, HSS, composites, and advanced materials (Zhang, W. & Xu, J. 2022). The upside of many of these options is the strength but the big downside is that they are quite expensive to produce compared to traditional materials. For example, by replacing steel with polyacrylonitrile-based carbon fiber reinforced polymer, the vehicle mass may be reduced by 60% but the cost would increase tenfold. The overall energy savings can also be questioned since the energy demand during manufacturing is large for materials like aluminum and magnesium during primary metal production, and, therefore, risks cancelling out the energy savings during the usage of cars (Czerwinski, F. 2021). The production of these material substitutes may therefore not lead to energy savings during the lifecycle. According to Das et al. (2016), however, the energy savings during the use-phase for most of the lightweighting conventional powertrains were higher than the increases in energy needed during manufacturing, resulting in energy savings in the overall lifecycle. It is, on the other hand, stated that efficient powertrains, including those with regenerative braking, already waste less energy and, therefore, the energy savings from lightweighting are less pronounced for these powertrains compared to the conventional ones.

7 Discussion

This study finds that an increasing vehicle mass and size, which is driven by consumer preferences, company strategies, and current policies, undermines the environmental benefits that electrification brings. Larger vehicles lead to larger energy needs, increased material demand, and a higher amount of emissions during the whole life cycle.

Combined findings from the literature, statistics, and interviews reveal a complex but consistent trend towards larger and heavier vehicles in Sweden. The literature points to an increasing consumer preference for larger cars. This is driven by factors like the comfort of having larger cars, the perceived safety aspects of a larger car, the need for a larger car depending on household size and the usage of cars as well as the economic incentives, such as the benefit car system reinforce the preference for large electric SUVs. Range anxiety is also likely pushing people to acquire larger electric cars than they might need. Even status and brand loyalty could still play a role in why cars get larger. Gender as a parameter has lost its importance in recent years, whereas this had a higher effect in previous years. The factors that encourage the most amount of people to downsize include the fuel economy and economic incentives. The personal economy is most often the deciding factor for which car a consumers choose to acquire. These findings show an increasing preference for larger, more comfortable cars with higher safety for the driver and passengers of the car. The change that could be seen for companies with a lower mean vehicle mass in the last two years could be an indicator that the vehicle mass will stop increasing as significantly as it has since company cars make up the majority of new car sales.

The statistical analysis also supports these findings by showing a clear trend towards heavier cars. It can also be seen from statistics of the most sold cars where SUVs dominate as the most newly sold car segment. The electrification process also contributes to cars becoming heavier. This trend towards larger and heavier cars suggests that consumer preferences and incentives for car purchases within Sweden do not yet align with sustainability goals from a material point of view, they do however promote BEVs through the benefit car system.

The statistics show a clear rise in the mean vehicle mass, no matter the parameter or car segment. However, opposite to what the literature suggested, the statistics showed that the difference in vehicle mass between income groups, household type, and age of consumers has shrunk compared to the year 2000. Consumers in the highest income quartile are the ones who purchase new cars to the largest extent, leading to them having the highest influence on which

cars come in on the second-hand market. The variables that have seen either increasing difference or sustained approximately the same significance are housing type and living area. People living in apartments and people living in urban areas purchase lighter cars on average. The findings from the statistics support the findings that the mean vehicle mass is increasing across demographics, but it also challenges the belief that demographics have a big effect on which car people get. It seems likely that the available range of cars and company strategies have a bigger effect on which cars people get than demographics do.

The interviews with experts highlighted several key points. While all agree that there are upsides to downsizing and that it could be beneficial to reduce emissions and the environmental impact, the automotive industry's strategies and focus on profitability and consumer preferences for larger cars will make such a transition difficult. Most also agree that a weight-based taxation scheme or incentivizing smaller cars could help with shifting consumer preferences, since economic factors are the driving factors. However, such policy measures must be balanced carefully to avoid unintended consequences such as hindering the electrification of the car fleet, increasing car ownership, or hindering social mobility.

The specific energy use model showed the impact that vehicle mass has on specific energy use during the use phase. It showed that ICEVs are affected to a higher degree by changes to the vehicle mass than BEVs, which can be explained by the fact that BEVs have higher efficiency. The same seems to be true for the frontal area of the cars, where ICEVs are more affected by changes. The vehicle mass as a variable does have an impact on specific energy use, and the downsizing of cars would likely lead to reductions in both vehicle mass and frontal size, which would result in even higher energy savings, no matter which car type.

In summary, there is evidence that downsizing of passenger vehicles would be environmentally beneficial, but there are significant barriers. The barriers include psychological and cultural barriers from consumers who often prefer larger cars and structural barriers, both from policies that focus on other issues and companies that are driven by profits. If these barriers are to be overcome, then coordinated efforts from policymakers are needed to push the industry and consumers in a desired direction. Without strong and targeted political interventions, the trend toward larger vehicles risks undermining decades of progress toward a sustainable transport sector within Sweden.

7.1 Possible Reasons Behind the Observed Trends

According to the statistics in the statistical analysis, cars seem to decrease in mean vehicle mass from 2004 forward to sometime in the 2010s. The reasons for this may be the EU CO₂ emission regulations that were implemented in 2009. These regulations aimed to have an average emission of 130 g CO₂/km (EUR-Lex, 2019). This was meant to encourage the car industry to invest in new technologies to meet the new emission standards. It likely also led to the production of lighter vehicles with lower emissions. The environmental class premiums that were given out in Sweden in the form of MB2007 and MB2013 were also likely contributors to cars decreasing in mean vehicle mass during this period, which was indicated in the analysis of the statistics. But after 2012 and forward the EU regulations were changed to be weight-based, meaning that cars with a higher vehicle mass were allowed to emit more CO₂ per kilometer (EUR-Lex, 2019).

The 2008 financial crisis may also have played a part in why people started choosing lighter cars. In a recession, many consumers are more likely to choose more economical and fuel-efficient cars. Since economic factors are the largest drivers for people, as found in interviews with experts, this likely has had a large impact on the market and the mass of cars sold during this period.

The reasons behind the trend towards larger and heavier cars could be several. Among these is the general shift towards the SUV segment of the market (Brand, 2024), increasing safety standards, higher levels of comfort, regulations based on CO₂ targets that are adjusted for mass in running order (Transport & Environment, 2021), a decrease in the number of new car buyers, and the gradual electrification of the car fleet.

As stated previously, the trend towards SUVs has been growing since 2010, leading SUVs to represent 48% of global new car sales (IEA, 2024). This is true for Sweden as well (Olander, 2023). SUVs are generally larger and heavier, and thus, the increased popularity of this market segment has likely led to a heavier vehicle fleet, on average. Meanwhile, the popularity of SUVs is likely not the only factor that has pushed the trend towards heavier and larger cars. Smaller cars have also become heavier due to new regulations, safety requirements, and increased comfort for drivers and passengers. As stated in the expert interviews, safety and emission standards are making cars both larger and more expensive. Cars are nowadays expected to include so many more features than previously, for example, comfort features, exhaust cleaning systems, more capacity for fuels or larger batteries, and

safety systems. For safety, a certain width is also required to protect against collisions from the side. All this combined has likely led to all cars becoming heavier and larger.

In addition, the EU has introduced CO₂ emissions standards that are adjusted for the weight of the car (Transport & Environment, 2021), which also affect new cars sold in Sweden (Ollevik, N, O., 2012). This leads to producers being able to sell larger and heavier cars more easily, which can make them more profitable than a smaller, cheaper car would be. It also seems likely that larger cars in the premium segment are easier to market in recent years, given the recent recession and the geopolitical turmoil. The average individual does not purchase a new car in the middle of a recession and instead turns to the second-hand market. Meanwhile, richer people may still be able to purchase new cars and are likely willing to spend a bit more money to gain more comfort and personal safety, as indicated in the expert interviews. This is due to consumers within the premium or luxury segments being less price sensitive. Benefit cars are also often stated as a contributing factor towards the trend of larger cars. Sweden's generous benefit car system has most likely resulted in a heavier fleet on average, according to the expert interviews.

Electrification has also contributed to a heavier fleet since BEVs weigh more than an ICEV equivalent. According to Kevin Heaslip (Center for Transportation Research, 2024), BEVs often weigh 30% more than comparable ICEV gasoline cars because of the weight of their batteries.

Another trend that may have affected the increasing mass of ICEVs is the increasing share of mild hybrids in new car sales. Mild hybrids have existed for many years with Toyota selling mild hybrid versions of the Toyota Crown executive sedan between 2002 and 2008 (75 Years of Toyota, 2012). A mild hybrid is an ICE car equipped with a smaller electric motor (often 48 48-volt motor), which is designed to lower the fuel consumption. When breaking, energy is stored in the battery, and when starting it is the electric motor that starts it. According to Volvo the mild hybrid technology can reduce the fuel consumption by up to 15% (Olsson, M., 2024). The extra weight that this system adds is quite small, but it might allow for getting larger ICE cars while keeping the low fuel consumption, since fuel consumption was proven as an important factor for many consumers.

7.2 Possible Future Trends

In the coming decades, electrification is expected to continue with more and more electric cars entering the fleet. This will likely result in the mean vehicle mass and size remaining high unless deliberate countermeasures are put in place, according to the expert interviews. Without intervention, this will result in a fleet that is made up of a majority of electric SUVs, many of which are first bought by companies through benefit car schemes that favor premium models with high benefit values. Consumers will most likely also continue favoring larger cars that give them higher perceived safety, more comfort, and a better lifestyle fit. Without new policies that favor smaller cars, downsizing will remain a niche that is driven by price-sensitive private buyers, who already don't purchase new cars to any large extent if at all. At the same time automakers will prioritize profits and continue focusing on premium vehicles since there is money in that segment.

The trend towards larger vehicles will likely plateau at some point since there is an upper limit on how heavy a car is allowed to be while still being able to drive using a driving license certified for passenger cars (B-class). At the same time, there is a proposal in the Swedish Riksdagen to increase the maximum weight a car can have while still being allowed to drive it with a driving license certified for passenger cars (B-class) (Riksdagen, 2024). The increase would be from 3,500 kg to 4,250 kg which would most likely lead to even larger cars on average. The mass of cars will likely plateau at a high level and with lightweighting, which could reduce vehicle mass by up to 48% by 2045, the cars could potentially become even bigger while still maintaining the vehicle mass below the limitations. This would result in a larger material consumption and more emissions during production. Unless targeted incentives are introduced, the sustainability benefits that electrification brings could be undermined. BEVs are still more beneficial for the environment than ICEVs, as was shown in the specific energy use model, but if electrification results in the use of oversized cars, then the inefficiencies of driving around in these oversized cars could reduce the benefits of electrification.

7.3 Limitations of the Study and Future Research

There were some limitations in this study, some that could not be influenced while others could have been if more time had been available. For the literature review, there is a large bias for studies in the global north. Most of the surveys studied in the literature were performed in Europe or North America. Since there is little representation from other parts of the world, the

results might not apply to other parts of the world. It would be beneficial for future studies to study surveys from other parts of the world to get a more global perspective on how consumer preferences may impact the passenger car market. Since this study focused on Sweden, that wasn't seen as necessary to understand consumer preferences, but it could be relevant for comparison with other cultures and countries. Sweden is also a small country that is affected by the development internationally. The Swedish consumers are only one of many that affect automotive producers and how they choose to prioritize between models and sizes of cars.

The statistical analysis was restricted by the confidentiality of the data that were used. Therefore, it was only possible to analyze one variable at a time to avoid disclosing information on small groups of individuals. This, unfortunately, limited the potential of multivariable analyses, where the impact of multiple demographic factors on vehicle size could have been explored. In future research, a multivariate regression model could be used to be able to assess the impact of multiple variables simultaneously, which could reveal if certain effects depend on a combination of factors or if factors like household size are more of a secondary factor that depend on income. Baltas & Saridakis (2013) applied multinomial logit models to analyze how demographics such as income, education, residential area, and gender affect the probability of choosing a certain car type. Such an analysis could help identify which sort of groups might be most susceptible to certain policy instruments and which groups are less likely to change their ways even with pressure from policymakers. Such an analysis could be one option for future research.

The interview results may have been biased by the views of the organizations that were chosen. The interviews gained insights into how certain organizations and companies perceive the preferences of consumers. An idea would be to conduct a survey with a Swedish focus to get a good understanding of the preferences that consumers in Sweden have. A lot of the information about how consumers think came from the literature review in this project, and a survey conducted completely within Sweden could be beneficial. Another idea to understand the Swedish consumer's preferences would be to conduct a longer study of individual consumer preferences over time and how they develop. This could reveal in greater detail what has the largest impact on preferences. But this sort of study would likely require a lot more time to carry through. It would also be interesting to see how automakers' marketing influences consumers' perceptions of car size, safety, and environmental performance.

The limitations of the specific energy use model were that it was both generalized and simplified. When testing the impact on vehicle mass and frontal area, they were changed one

at a time since there isn't a clear relationship between vehicle mass and frontal area necessarily, because of light weighting. For the ICEVs, there were also simplifications, as explained in the method that the efficiency for ICEVs depends on the motor speed, while in the model, it was a constant value. If a higher accuracy is desired, this relationship between motor efficiency and motor speed should be implemented.

8 Conclusion

The purpose of this study was to increase the understanding of consumers preferences regarding vehicle size. This can help in understanding how preferences affect energy use, material needs, and CO₂ emissions during the whole lifetime. By combining a mixed-methods approach, including a literature review, statistical analysis, interviews with experts, and a specific energy use model, this study has provided a comprehensive overview of the complex factors that drive the trend towards ever larger and heavier passenger cars, its impact on energy use, and the barriers to downsizing.

The factors that influence consumer preferences when buying a car are several. The findings of this study show that the preferences of consumers are increasingly shifting towards larger vehicles. The driving factors are of both practical and psychological importance. Practical reasons include cargo space, comfort, lifestyles, and personal safety. Psychological reasons include the importance of status, range anxiety, and perceived increased safety from larger vehicles. The statistical analysis also confirms that despite historical differences across income, household type, housing type, residential area, ages, and genders in terms of chosen vehicle mass at time of purchase, the preference for larger and heavier cars has become more widespread across all demographics. However, the demographical factors that have the largest effect on size seem to be residential area and housing type. The specific energy use modelling and the results from earlier research also showed that increasing vehicle size significantly increases the specific energy use of vehicles and the emissions related to vehicle manufacturing. This could lessen the potential environmental benefits that electrification brings, while BEVs will still be more beneficial than ICEV equivalents.

The potential savings from downsizing are many. The specific energy use model, several life cycle assessments and other literature confirm that the vehicle size and mass significantly impact both specific energy use as well as lifecycle energy use and CO₂ emissions. Larger and heavier vehicles require more material and use more energy both during production and

during the use-phase. Reducing the vehicle mass by 10% could result in a specific energy use reduction of more than 5%. If downsizing becomes widespread, large savings in terms of raw material demand, energy use, and CO₂ emissions can be expected. Downsizing may therefore be a powerful complement to electrification in reaching current climate goals.

The key insights from this study are many. Downsizing faces both physical and psychological barriers due to perceived trade-offs in comfort, safety, status, and utility, even though most consumers may not fully utilize the benefits that a larger car offers. Policy instruments are likely to be vital for a change to happen. The interviewed experts stressed that change is not likely to occur without policy measures. Potential measures include weight- or size-based taxation on cars, a feebate system, revised benefit car taxation, and a change in urban design to promote cars of smaller sizes. Financial incentives will likely have the largest impact since that has been stated as one of the most important factors in the decision to purchase a new car.

Electrification plays an important role in reaching Sweden's climate goals for 2045. This study highlights that vehicle size also significantly influences both specific energy use and lifecycle emissions. Downsizing could serve as a valuable complement to electrification for Sweden to reach its climate targets. This study contributes to a better understanding of consumers preferences and the current trend towards larger and heavier passenger cars and may help in developing future strategies for encouraging more sustainable choices.

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Appendix A

Tack för att du tar dig tiden att genomföra denna intervju med mig idag.

Denna intervju är en del av ett examensarbete som har som mål att förstå konsumenters preferenser när det kommer till införskaffandet av bil. Förhoppningen är att förstå hur preferenser påverkar möjligheter till att minska storleken på bilar. Detta då en minskad bilstorlek kan leda till hållbarare bilar som kräver mindre material vid produktion och mindre energi under hela livsryteln.

Dina svar kommer endast att användas i detta arbete. Är det okej om jag spelar in intervjun för att säkerställa att jag fångar dina svar korrekt?

- Vill du börja med att introducera dig och din roll lite kort?

Eftersom denna intervju handlar om konsumenters preferenser kring bilar så tänkte jag höra med dig,

- Vad har du för preferenser gällande storlek när du väljer en ny bil?
 - Vad är anledningen till att du föredrar?

Konsumenters preferenser:

Det finns såklart många faktorer som påverkar hur konsumenter väljer bil, men jag skulle vilja höra eran syn på konsumenters preferenser.

- Vad ser ni på [] som de viktigaste faktorerna som påverkar konsumenternas preferenser för fordonsstorlek?
 - Hur påverkar bränsleeffektiviteten konsumenters val?
 - Hur påverkar säkerhet och komfort konsumenters val?
- Hur tror ni att konsumenternas attityder till mindre fordon har förändrats de senaste åren?

Trender:

Nu tänkte jag gå in på trenden inom bilmarknaden. Under 2023 stod privatbilar för ungefär 10% av globala utsläpp vilket transportsektorn försöker ändra på genom att övergå till eldrivna bilar. Samtidigt så står stora bilar för en stor andel av nyregistrerade bilar i Sverige. SUVar stod för omkring 48% av nyregistrerade bilar i Sverige år 2023. Många forskare menar att en ökad storlek på elbilar kan underminera övergången från fossildrivna bilar till elbilar.

- Vad är [] uppfattning av trenden inom bilmarknaden när det gäller storlek på fordon?
- Hur tror ni på [] att trenden inom bilmarknaden kommer utvecklas? Kommer det fortsätta att bli allt större bilar i framtiden?
 - Finns det problem med denna framtida trend?
- Vad skulle kunna påverka trenden som går mot allt större bilar?
 - Är politiska styrmedel som beskattning av tunga bilar eller förmåner för små bilar till exempel subventioner ett bra alternativ för att påverka konsumenters köpvanor?

Möjligheter och hinder:

Utöver att mindre bilar kräver mindre material och energi så har det även visats att ju större bilar blir desto större blir chansen att trafikolyckor inträffar. Om man då vill minska storleken på bilar både för miljöaspekter men även för säkerheten på vägarna.

- Vad finns det för möjligheter att minska bilstorlekarna, vad skulle kunna motivera konsumenter att välja mindre bilar?
 - Vilken roll bör företag, media och politiker ta för att få till en förändring?
- Vilka är de största hindren som hindrar konsumenter från att minska storleken på sina fordon?
 - I och med övergången till elbilar kommer bränslekostnader ha en mindre inverkan på konsumenters val?
 - Är det rymligheten som lockar?

- Är säkerhetsaspekten viktig?

Om man då trots allt skulle få till en förändring inom transportsektorn som leder till en minskad personbilar

- Ser ni hos [] några nackdelar med att minska storleken på bilar?
 - Mindre vinst vid försäljning?
 - Mindre valmöjlighet?
 - Potentiellt mindre räckvidd? Förknippas små bilar med små batterier?
- Vilka fördelar ser ni med att minska storleken på bilar?
 - Hur skulle säkerheten på vägarna påverkas?
 - Lägre priser på bilar?
 - Mindre klimatpåverkan?
 - Renare luft?

Tack så mycket att du tog dig tid för denna intervju. Innan jag avslutar undrar jag om det är något mer du skulle vilja tilläga som kan vara viktigt i denna diskussion?

Appendix B



Figure 21: Confidence intervals for all gasoline cars (left) and newly sold gasoline cars (right) depending on income quartile.



Figure 22: Confidence intervals for all diesel cars (left) and newly sold diesel cars (right) depending on income quartile.

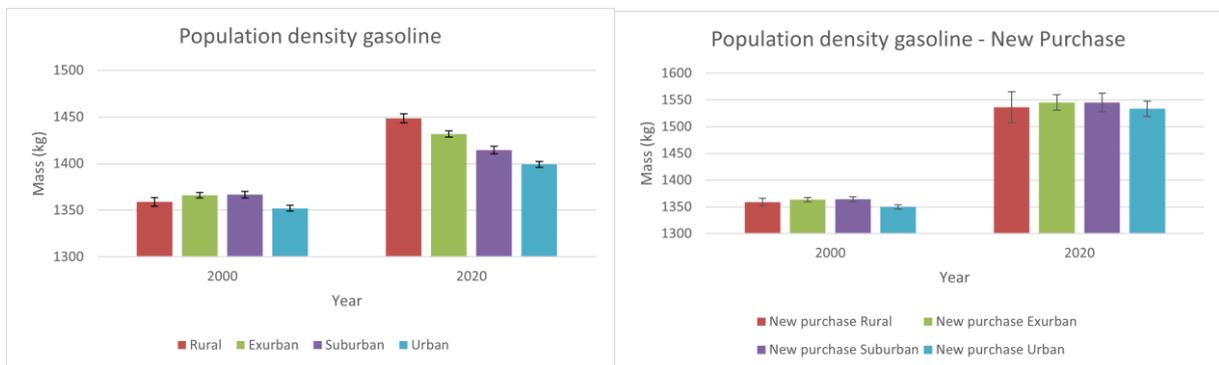


Figure 23: Confidence intervals for all gasoline cars (left) and newly sold gasoline cars (right) depending on population density.

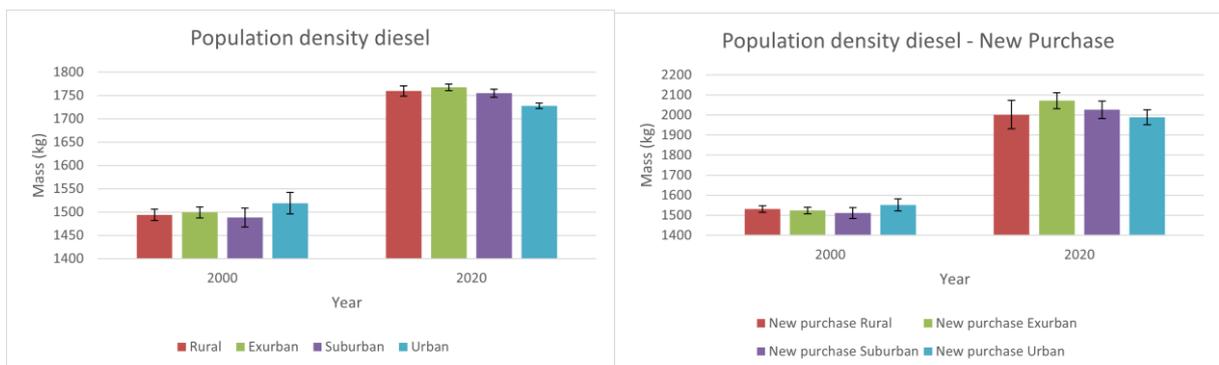


Figure 24: Confidence intervals for all diesel cars (left) and newly sold diesel cars (right) depending on population density.

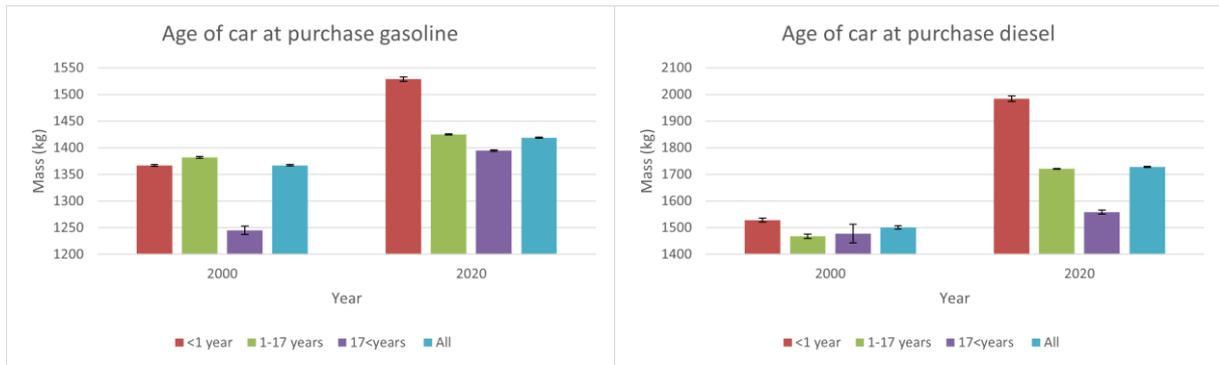


Figure 25: Confidence intervals for gasoline cars (left) and diesel cars (right) depending on age of car at purchase.

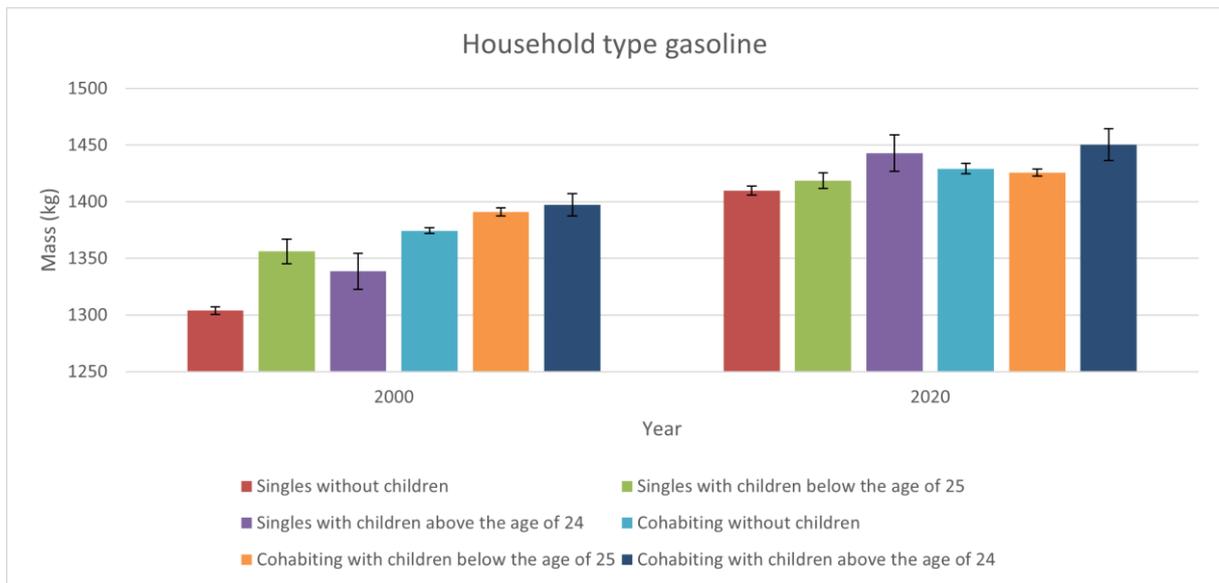


Figure 26: Confidence intervals for all gasoline cars depending on household type.

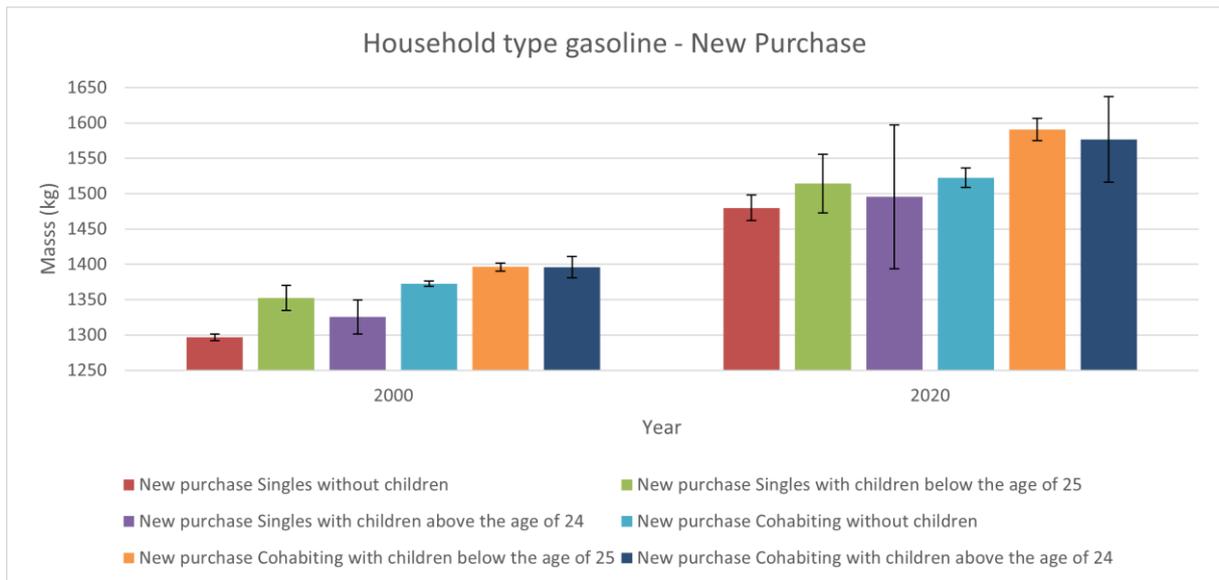


Figure 27: Confidence intervals for all newly sold gasoline cars depending on household type.

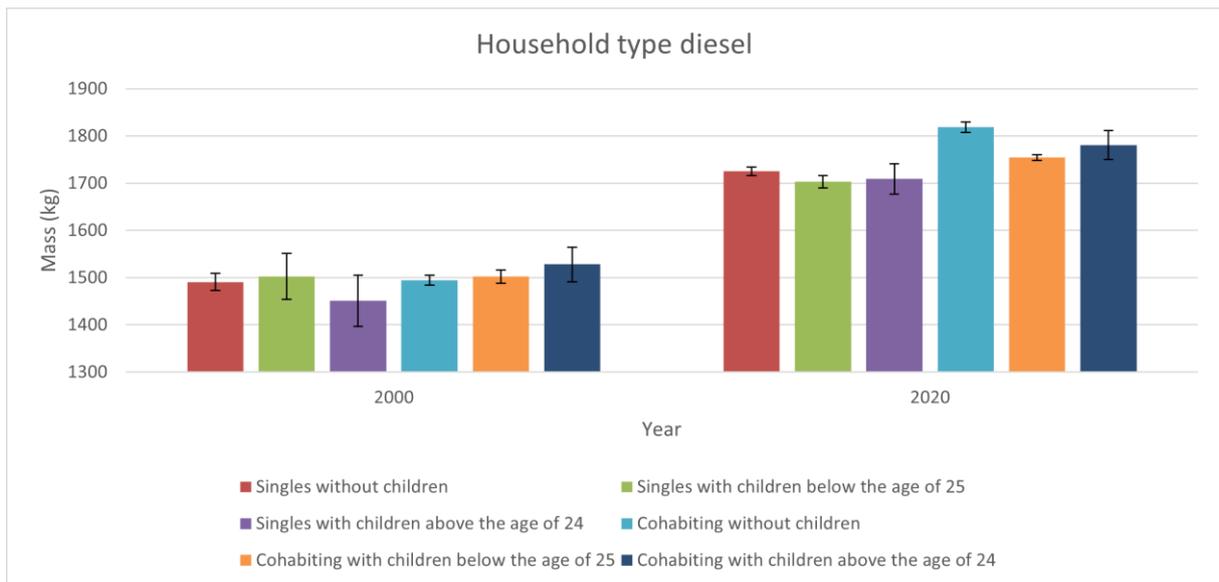


Figure 28: Confidence intervals for all diesel cars depending on household type.

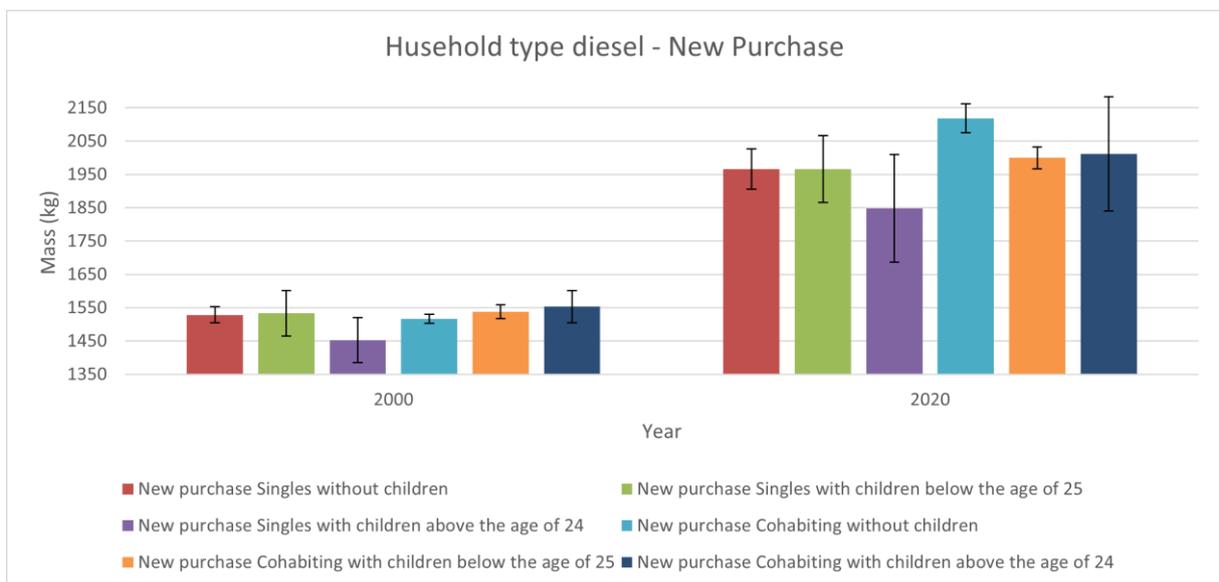


Figure 29: Confidence intervals for all newly sold diesel cars depending on household type.

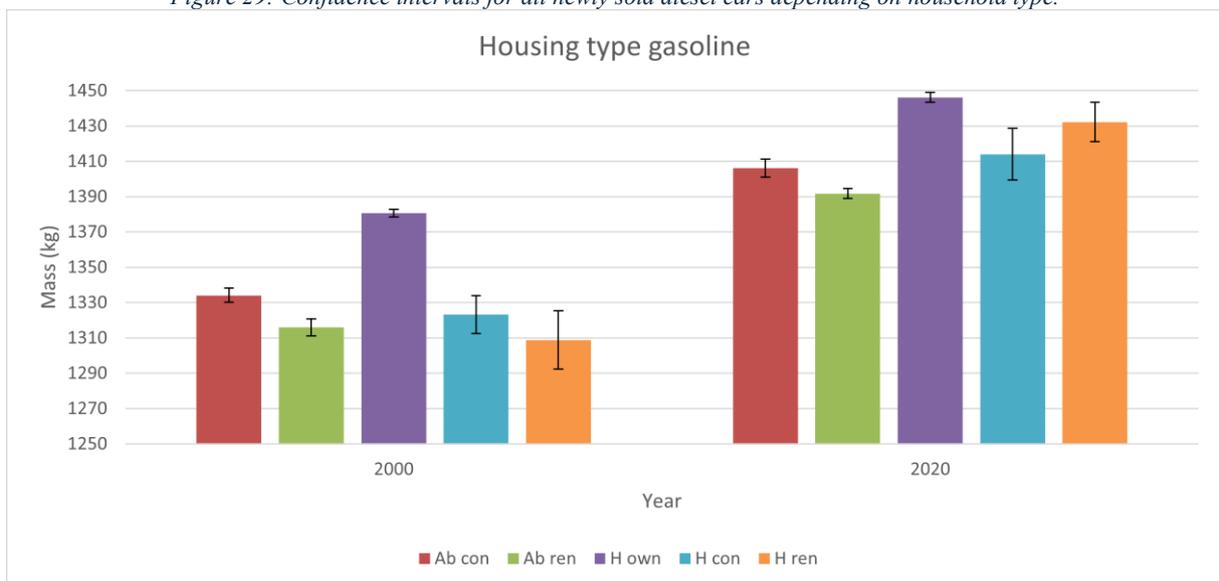


Figure 30: Confidence intervals for all gasoline cars depending on housing type.

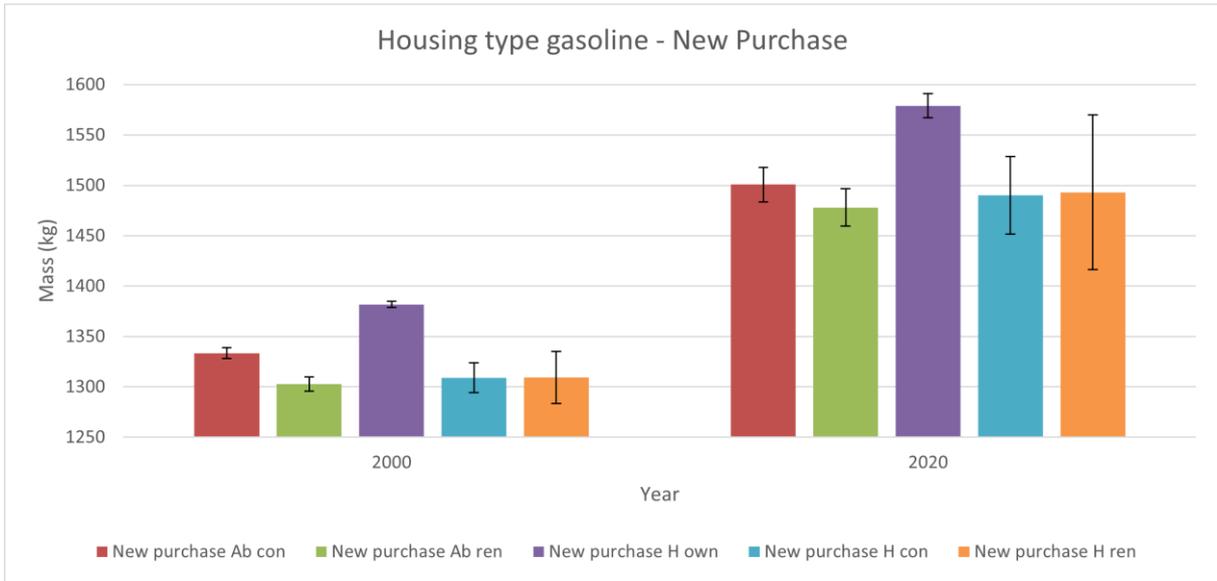


Figure 31: Confidence intervals for all newly sold gasoline cars depending on housing type.

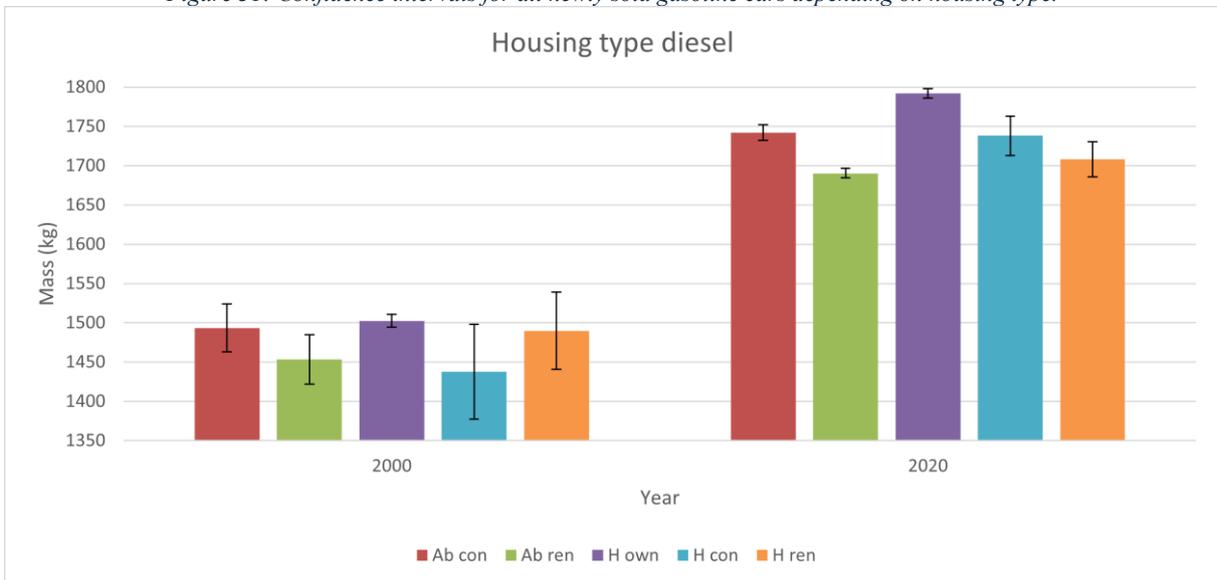


Figure 32: Confidence intervals for all diesel cars depending on housing type.

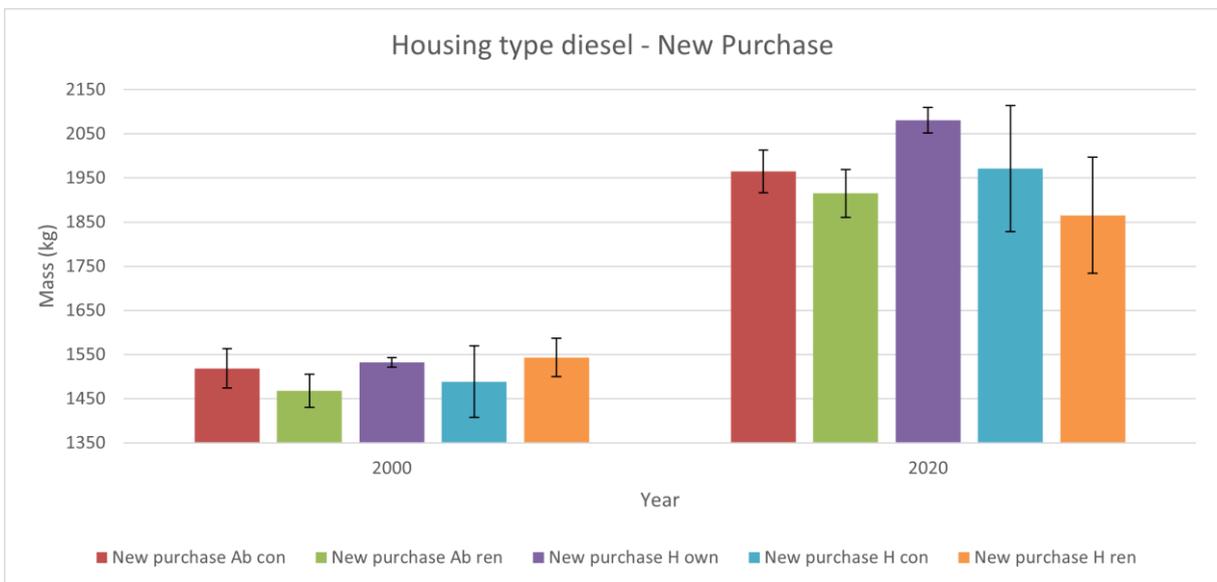


Figure 33: Confidence intervals for all newly sold gasoline cars depending on housing type.

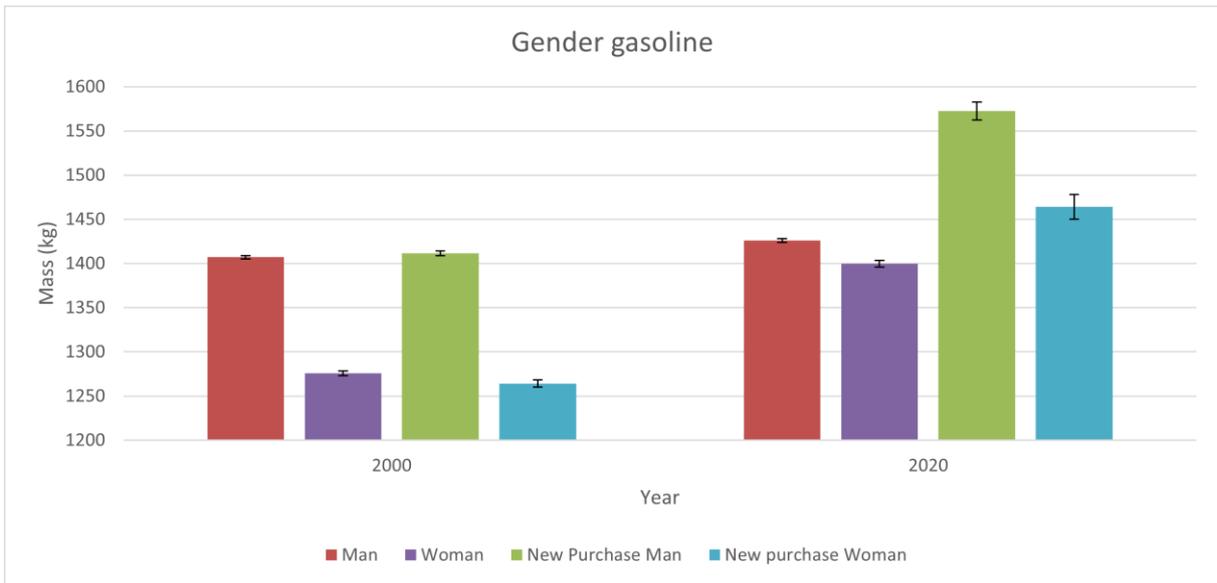


Figure 34: Confidence intervals for all gasoline cars and newly sold gasoline cars depending on gender.

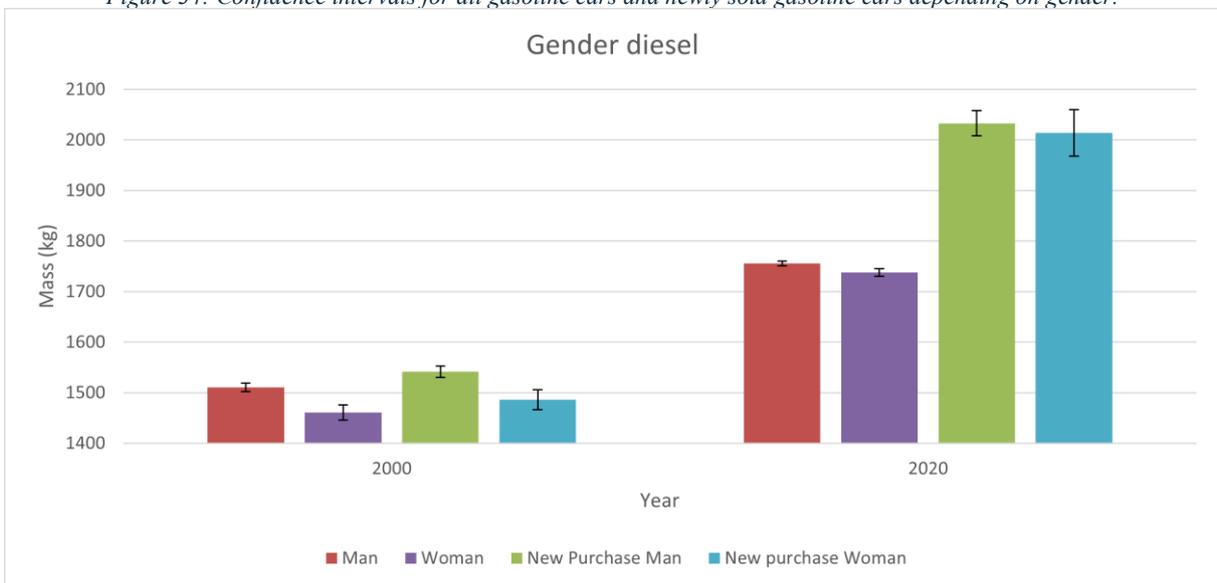


Figure 35: Confidence intervals for all diesel cars and newly sold diesel cars depending on gender.

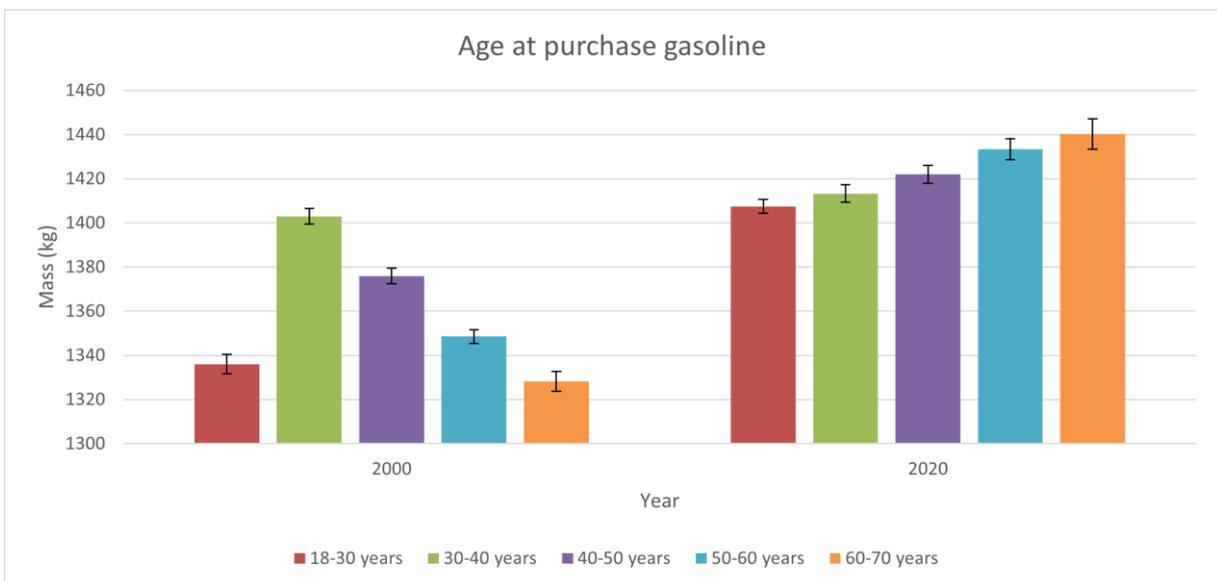


Figure 36: Confidence intervals for all gasoline cars depending on the age at purchase.

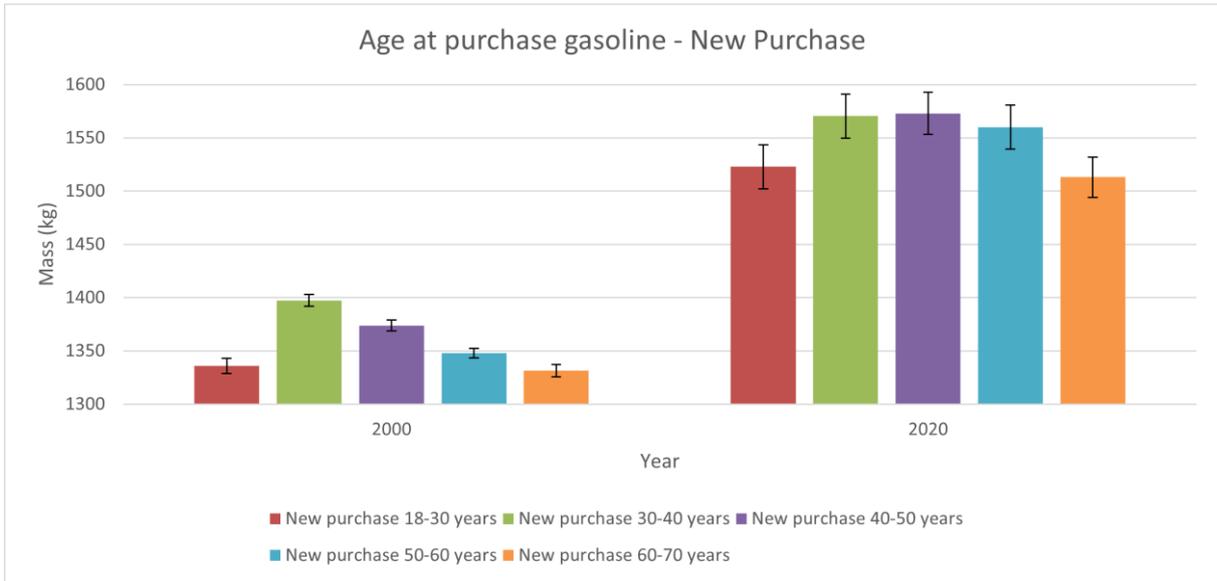


Figure 37: Confidence intervals for all newly sold gasoline cars depending on the age at purchase.

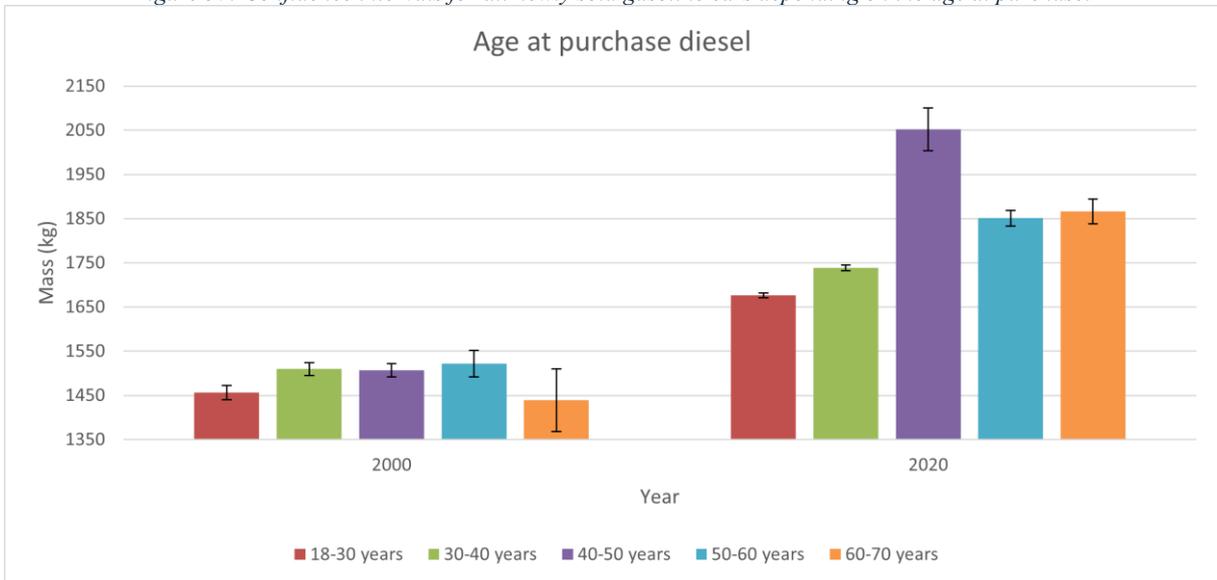


Figure 38: Confidence intervals for all diesel cars depending on the age at purchase.

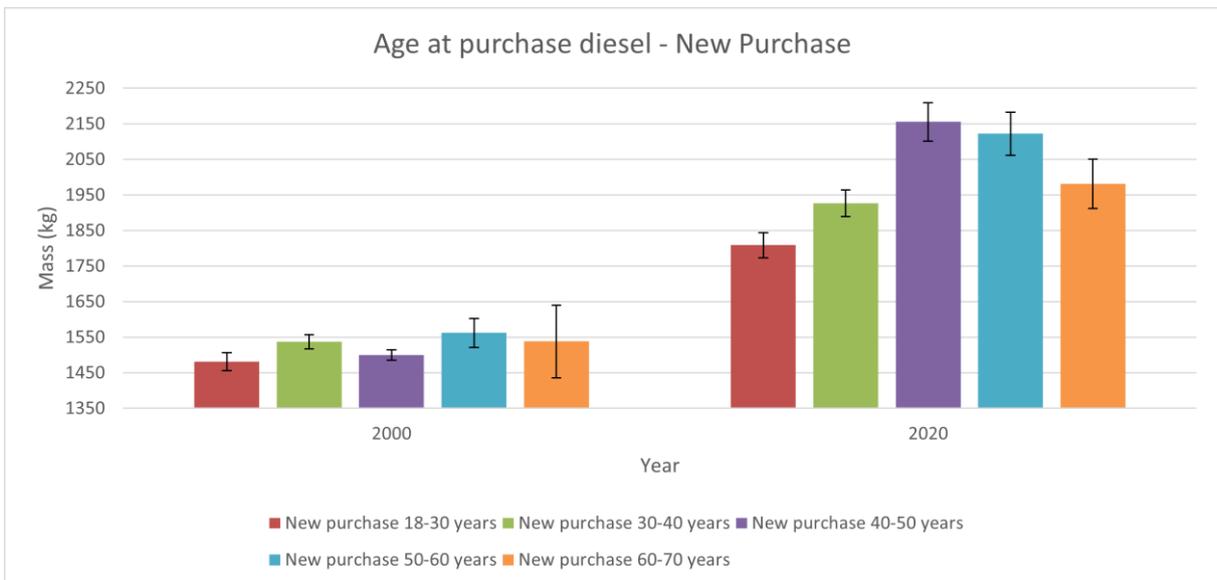


Figure 39: Confidence intervals for all newly sold diesel cars depending on the age at purchase.

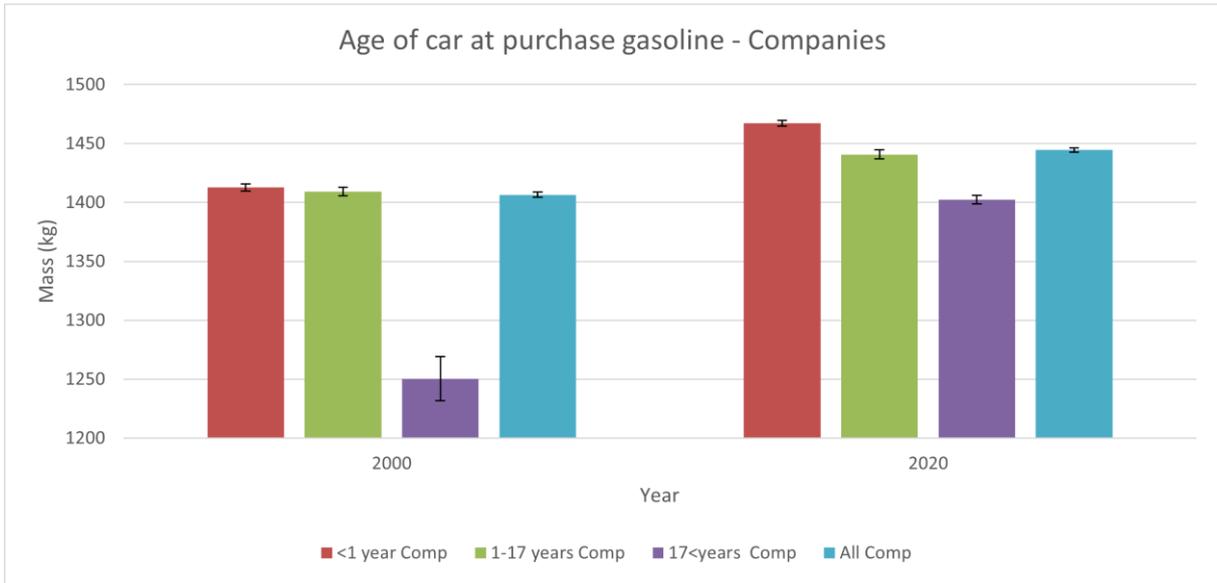


Figure 40: Confidence intervals for all gasoline cars depending on the age at purchase for companies.

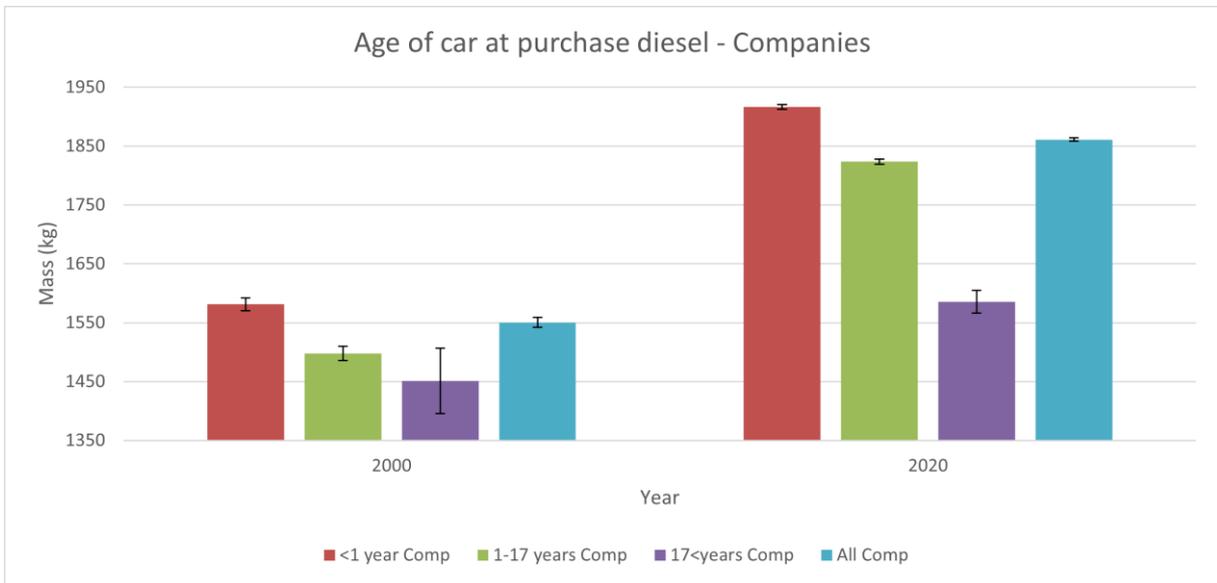


Figure 41: Confidence intervals for all diesel cars depending on the age at purchase for companies.

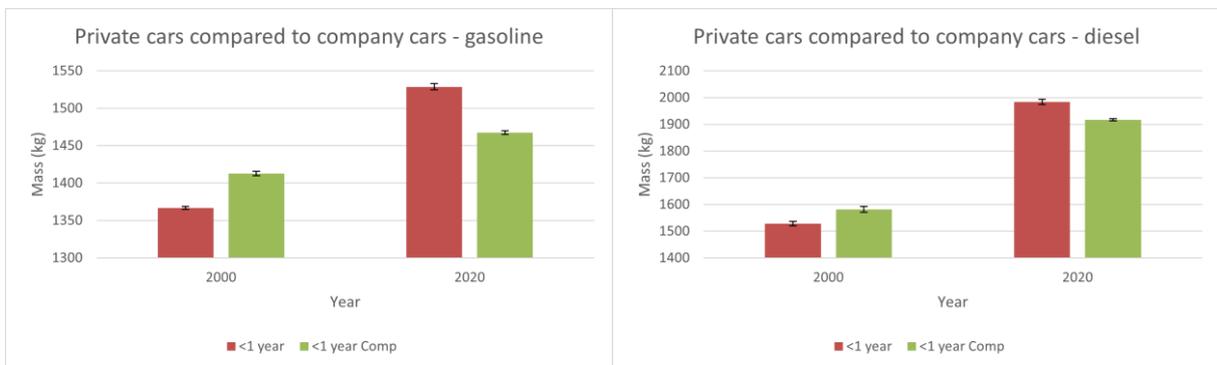


Figure 42: Confidence intervals for all newly sold gasoline cars (left) and all newly sold diesel cars (right) when looking at private cars compared to company cars.

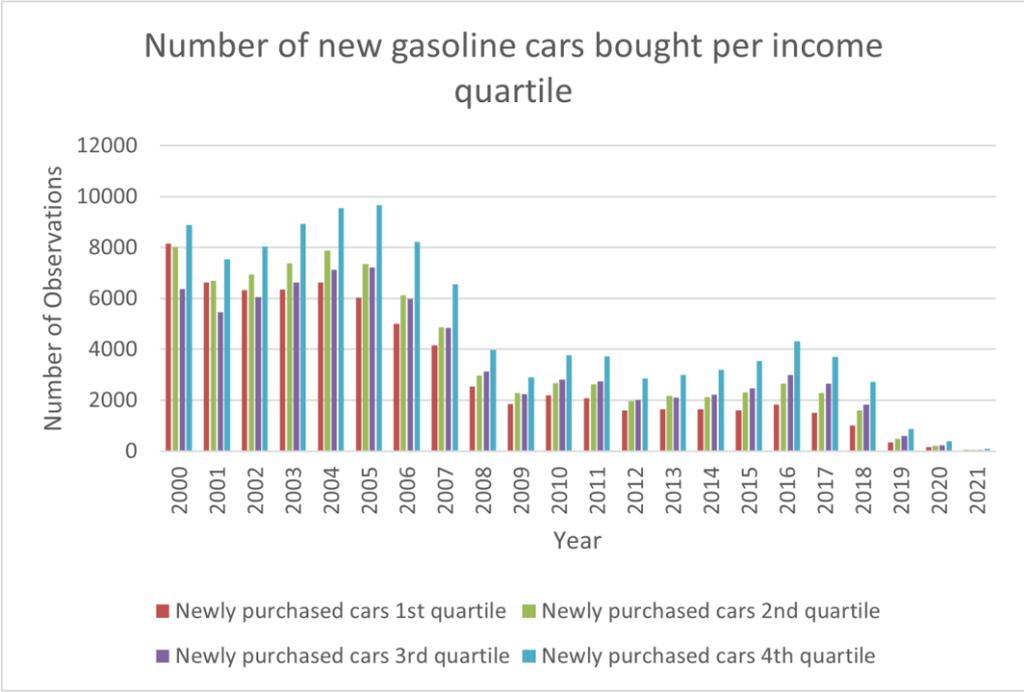


Figure 43: Sample sizes for newly bought gasoline cars depending on income quartile.

Appendix C

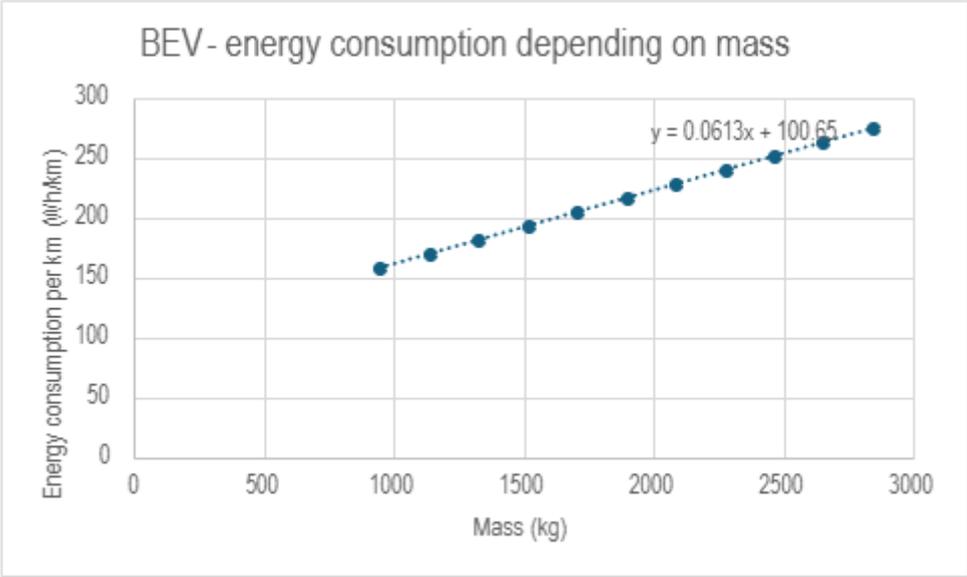


Figure 44: Linear regression for how BEV cars specific energy use is impacted by changes in the vehicle weight.

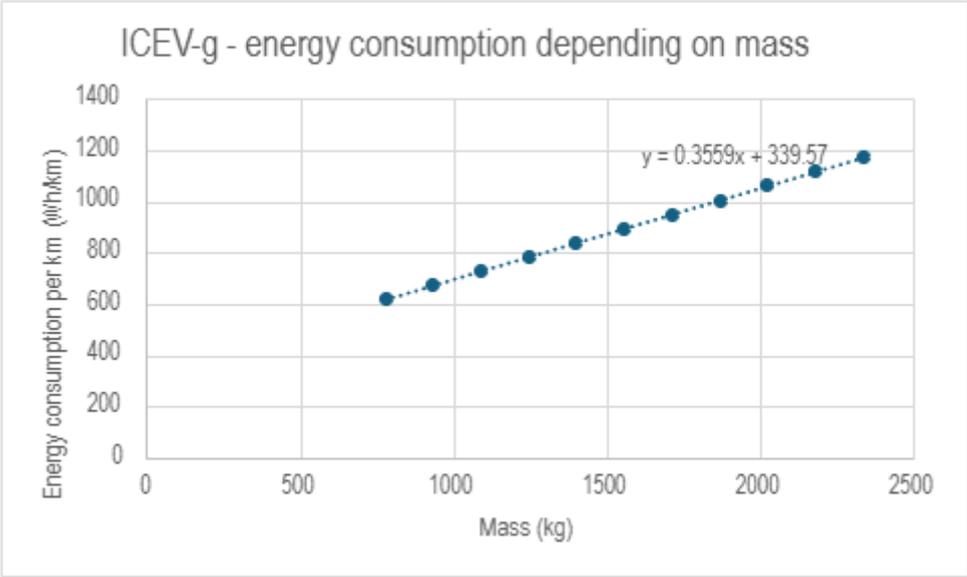


Figure 45: Linear regression for how ICEV-gasoline cars specific energy use is impacted by changes in the vehicle weight.

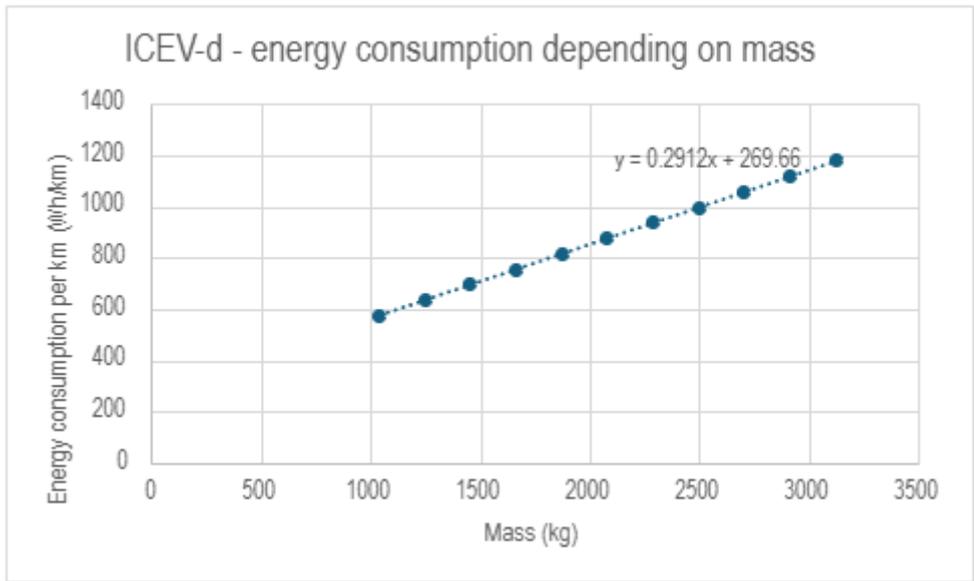


Figure 46: Linear regression for how ICEV-diesel cars specific energy use is impacted by changes in the vehicle weight.

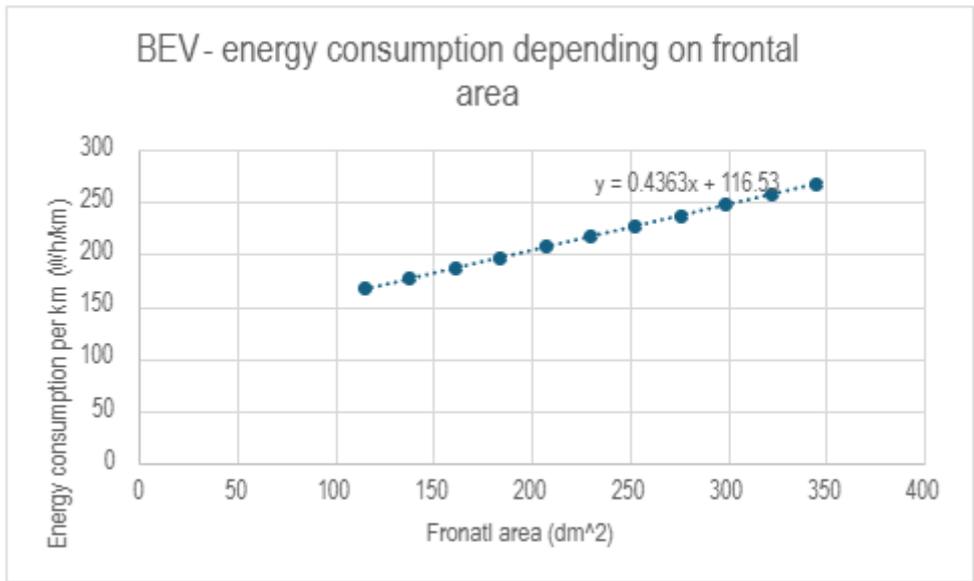


Figure 47: Linear regression for how BEV cars specific energy use is impacted by changes in the frontal area of the car.

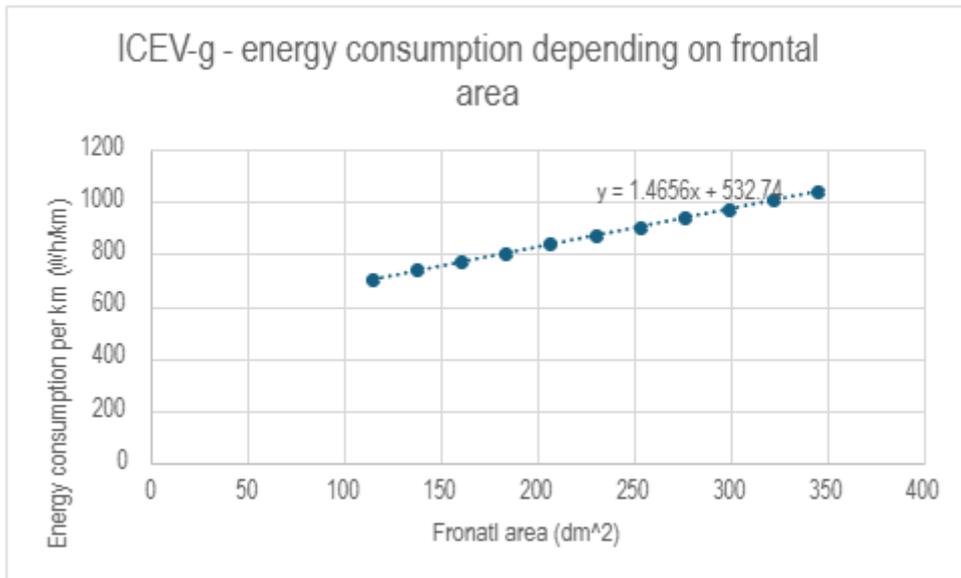


Figure 48: Linear regression for how ICEV-gasoline cars specific energy use is impacted by changes in the frontal area of the car.

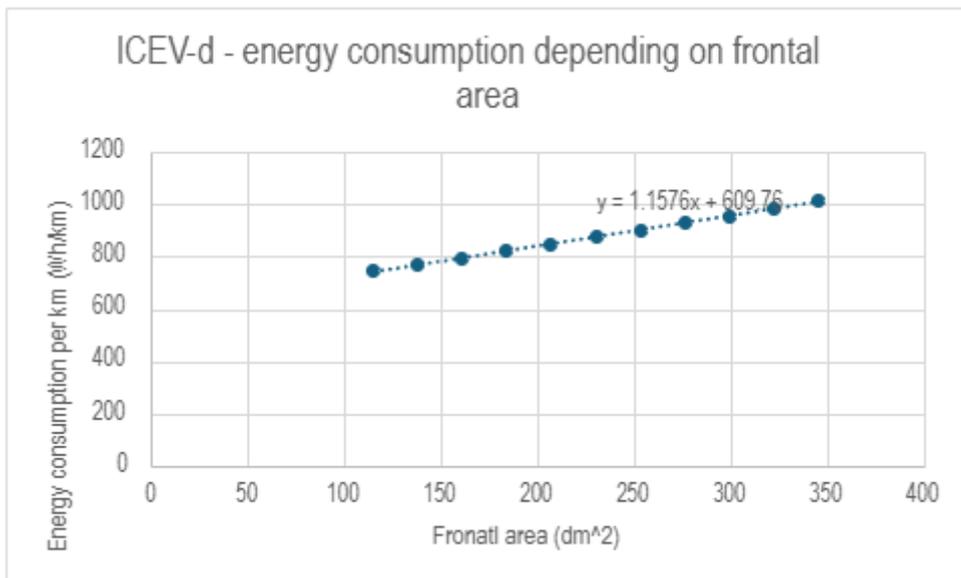


Figure 49: Linear regression for how ICEV-diesel cars specific energy use is impacted by changes in the frontal area of the car.