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Energy consumption patterns for mobility
in Austrian households:
A socio-economic analysis

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List of Acronyms/Abbreviations

AG21	(Agenda 21)
ANOVA	(Analysis of Variance)
BMLFUW	(Bundesministerium für Land-, Forst-, Umwelt- und Wasserwirtschaft; Austrian Ministry of the Environment)
DFA	(Discriminant function analysis)
EU	(European Union)
GDP	(Gross Domestic Product)
GHG	(Green House Gas)
MANOVA	(Multivariate Analysis of Variance)
SERI	(Sustainable Europe Research Institute)
SEU	(Styles of energy use)
UN	(United Nations)

VCÖ

(Verkehrsclub Österreich)

WCED

(World Commission on Environment and
Development)

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1. Introduction and Background

1.1. Introduction

As stated by Nath (2003) one of the most serious threats and barriers in the developed world in terms of achieving sustainable development are the persistently rising production and consumption which is emanating from environment-degrading life-styles. This looming trend of production and consumption has been recognized by various institutions and put on their agenda.

According to the Brundtland Commission Report "Our Common Future" (WCED 1987, 8: Industry: Producing More With Less) during 1950 the world produced only one-seventh of the goods as it did these days which means that the production of consumer goods has been raised by a factor of seven. However, we can assume that the factor today (2010) is significantly greater. Consequently greater production means greater consumption of energy and natural resources notwithstanding recycling and reuse efforts, matching amounts of both production and post-consumption wastes to be disposed of, and the environmental consequences of all these.

As a consequence of generally rising production and consumption patterns the Brundtland Commission Report stresses the issue that the adoption of less consumptive and less polluting life-styles, especially by the developed countries, is a necessary pre-condition for progressing towards global sustainable development.

Therefore in 1993 the United Nations (UN) proposed the Agenda 21 (AG21) document as one of the outcomes of the Rio de Janeiro conference in 1992. In chapter 4 two objectives were stated regarding the importance of sustainable production and consumption:

- To promote patterns of consumption and production that reduce environmental stress and will meet the basic needs of humanity.
- To develop a better understanding of the role of consumption and how to bring about more sustainable consumption patterns.

(UN 1993, Art. 4.7.)

However, in order to meet the abovementioned objectives concerning a better understanding of consumption patterns as a *conditio sine qua non* for promoting more sustainable consumption, a representative and comprehensive database, availability of information and an extensive scientific analysis thereof will be indispensable. Such a database would foster the in depth understanding and underlying mechanisms and therefore the implementation of demand oriented, targeting and sustainability promoting consumption policies.

Since the implementation of AG21, several measures and EU directives are setting the framework for national policies. Especially the EU White paper (2001) on transport policy provides measures to be taken at Community level as a first essential step towards a sustainable transport system. These measures all together are targeting the local and national level respectively. Therefore the establishment and analysis of national data bases would be a reasonable first step.

This picture of rising consumption trends is particularly true for energy consumption in the field of passenger transport or private mobility of households as described by the following paragraph.

As stated by various institutions the importance of transportation in general and its related impact on the environment as well as on society has grown over the last decades (Commission of the EU, 2001; BMLFUW, 2001; INFRAS/IWW, 2004; Verkehrsclub Österreich, 2008; IEA, 2007, 2009b).

The International Energy Agency (IEA) examined various aspects concerning passenger transport over the period 1990 to 2004 in 17 IEA member countries including Austria. The report revealed the following findings (Fig.1):

- Total final energy consumption in domestic passenger transport (excluding international air travel) increased by 25 percent
- Carbon dioxide emissions rose by 24 percent
- Trends in total final energy consumption and carbon dioxide were driven largely by a 31 percent increase in passenger travel, measured by the number of passenger-kilometres.

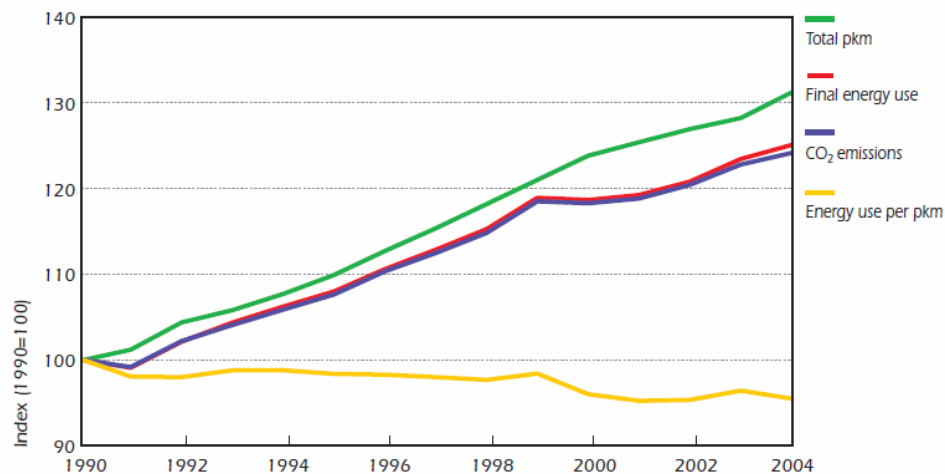


Figure 1: Overview of key trends in passenger transport. Source: IEA, 2007

These data clearly demonstrate that energy consumption, related resource use and environmental impacts originating from passenger transport or respectively household mobility have grown over the last decade.

However, the current situation about private mobility concerning available data on the national as well as on the international level is rather insufficient as described in the later section of this work. As a consequence a comprehensive analysis of private mobility consumption patterns in order to provide profound knowledge about its key drivers is missing.

This study investigates private mobility consumption patterns of Austrian households, which have been characterised by socio-economic variables. Essential to this work is that these consumption patterns are to a large extent influenced by various socio-economic variables. Therefore the study aims at describing Austrian private mobility patterns and overall private mobility energy consumption at the household level by relating to socio-economic variables.

The key aspect of this research is to establish the link between private mobility consumption patterns and socio-economic variables on the household level in order to come up with a more differentiated and detailed picture of private mobility consumption patterns. This essentially paves the way for the development of more demand oriented and targeted measures

and policies in order to set the framework for more sustainable consumption patterns.

In the first section of this study current problems emanating from transport, data availability of consumption patterns and its socio-economic key drivers will be addressed. This argumentation will act as a basis for further analysis of socio-economic differentiation. To this end statistical techniques will be applied in order to explore mobility energy consumption patterns of Austrian households. Results of socio-economic key drivers will be compared to present findings in research and potential implications for policies and measures will be discussed.

1.2. Statement of Research Problem

Transport is an essential factor of economic development and human welfare. But at the same time transport gives rise to a wide set of environmental as well as social externalities. Regarding environmental indicators such as airborne pollution, greenhouse gas emissions, land use, etc. the transport sector is already now the sector with the fastest growth in terms of environmental impacts. Beside these environmental costs external effects with social implications like passenger safety and security, public health, noise and congestion exist within the transport system.

A study done by the Swiss institute INFRAS in cooperation with the German IWW (2004) addresses marginal costs of all transport modes at the global level (Fig. 2) by taking account of external impacts (environmental damages, accidents, congestion). The study estimated global costs of 650 billion Euros for the year 2000. The highest contributors to total external costs are climate change (30 percent), air pollution (27 percent) and accidents (24 percent).

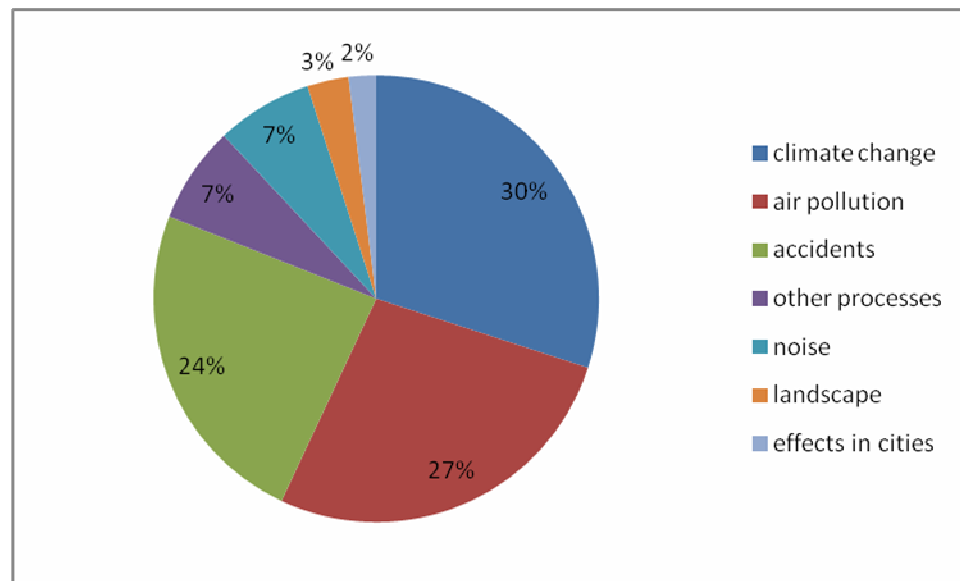


Figure 2: Estimated external costs of world traffic and transportation (displayed in figure by share of impacts in the year of 2000). Source: adapted from INFRAS/IWW, 2004 in VCÖ, 2008

Special emphasis is given to the studies of the International Energy Agency (IEA) which provides important insights about current energy use and carbon dioxide emission patterns. The IEA (2009a) estimated in 2007 that at the EU level the transport sector is responsible for about 25 percent of energy-related GHG emissions and that the transport sector shares 61.2 percent of world oil consumption (IEA, 2009b).

Especially the examination of the passenger transport sector in 17 IEA countries over the period 1990 to 2004 reveals profound findings.

Box-text: Key findings of passenger transport over the period 1990 to 2004.

- Total final energy consumption in domestic passenger transport (excluding international air travel) increased by 25 percent; carbon dioxide emissions rose by 24 percent. These trends were driven largely by a 31 percent increase in passenger travel, measured by the number of passenger-kilometres.
- Cars are responsible for the largest share of energy use in domestic passenger transport, accounting for 88 percent of the total in 2004. In most countries, cars remain almost exclusively dependent on oil. Europe has seen a significant increase in the penetration of diesel as a fuel. The share of biofuels is still small, but is also growing in some countries.
- Domestic air travel is the fastest growing mode of transport, and was 61 percent higher in 2004 than in 1990. In contrast, the shares of bus and rail travel have declined.
- The energy intensities of all passenger modes have declined, with a particularly strong decrease for domestic air travel. Overall, the energy intensity of passenger transport reduced at an average rate of 0.5 percent per year. However, this rate of reduction was much lower than in previous decades; a fall of 1 percent per year was seen between 1973 and 1990.
- Without the energy savings resulting from reductions in energy intensity, final energy consumption in passenger transport would have been 7 percent higher in 2004. This represents an annual energy saving of 2.1 EJ and 150 Mt of avoided carbon dioxide emissions.

Source: adapted from IEA, 2007

Considering the key findings of the IEA in the future the environmental impact of passenger transport concerning final energy consumption can be regarded as a fundamental barrier in pursuing a sustainable pathway of economic and social development.

The Intergovernmental Panel on Climate Change (IPCC) concludes that the transport sector plays not only a crucial and growing role in world energy use but also in emissions of GHGs. Because of the fact that

economic growth fuels transport demand and the availability of transport drives development, by facilitating specialisation and trade, transport activities and related energy use and emissions will continue to increase in the future.

Another important aspect stressed by the report of the IPCC is that the majority of the world's population still does not have access to personal vehicles and many do not have access to any form of motorized transport, but this situation is rapidly changing as transport activity in emerging economies is expected to grow robustly over the next several decades. The sectors propelling worldwide transport energy growth are primarily light-duty vehicles, freight trucks and air travel, whereas light-duty vehicles and air travel are important aspects related to energy consumption at the level of households.

Another factor that has accelerated the increase in transport energy use and carbon emissions and related to the mobility consumption patterns of households mainly in developed countries is the gradual growth in the size, weight and power of passenger vehicles. Despite gains in overall vehicle efficiency in the last decades most of these improvements have gone towards increased power and size at the expense of improved fuel efficiency.

Intercity and international travel is growing rapidly, driven not only by growing international investments, reduced trade restrictions and increases in international migration but also by rising household incomes that fuel an increased desire for recreational travel. (IPCC, 2007)

Concerning the Austrian context, mobility consumption patterns have been reviewed in the latter part of this study (1.6. Study area location and description).

1.3. Objectives

The overall aim of this study is to examine the energy consumption for mobility of Austrian households and its relationship to specific socio-economic aspects.

In detail, three interrelated specific objectives are set forth in order:

- To describe household structures with regard to socio-economic aspects and their correlation to private mobility energy consumption patterns
- To assess household mobility energy consumption according to socio-economic characteristics of households
- To explore patterns and clusters of private mobility energy consumption

1.4. Research Hypothesis

As far as we know from literature we can conclude that drivers of energy consumption patterns in general or attributed to the area of household mobility are manifold and comprise a web of aspects which are either mutually reinforcing or defanging and widely varying in their importance and influence.

In order to unfold these uncertainties about their importance and influence on energy consumption in the area of mobility a comprehensive analysis of the key components of total energy consumption – covering aspects of structure and quantity of energy consuming entities, quality of energy consuming entities and style and frequency of utilization – is imperative to fully understand the impact of drivers.

Therefore the study is guided by the assumption that socio-economic aspects are the key components in determining the underlying structure and patterns which comprises the total energy demand of Austrian households in the mobility sector.

1.5. Human Ecological Approach

Human Ecology as a field of research develops an understanding of the inter-relationship between humans and their environments. Essentially it seeks to describe the characteristics of a human and modern complex society by investigating its social and institutional arrangements and how society influences and regulates the material and energy transformations through which it relates to its supporting ecosystems. As concluded by Lawrence (2003) other disciplines beside Human Ecology lack the capacities for comprehending this relationship in a holistic way.

Human-ecosystem interaction is sustainable when the social system and the ecosystem are coadapted, whereby sudden changes in the social system or ecosystem can hamper the potential of coadaptation. Consequently these changes are affecting the ability of ecosystems to provide essential services. As a possible source, social forces cause the unsustainable relationship between modern social systems and the ecosystems. (Marten, G. 2001)

In the context of this study the aspects of mobility in human society, strongly influenced by lifestyle aspects in terms of high demand of individual mobility and the combustion of fossil fuels, are negatively impacting on ecosystems and therefore are responsible for this unsustainable relationship.

The Human Ecological Approach (HEA) tries to embrace a holistic approach by taking into consideration the complexity and adaptive capacity of its systems under investigation; essentially the human-ecosystem interaction.

This study is focusing on households which can be regarded as the smallest social entities or systems. Because of the fact that most of the consumer activities take place within the households, while its members are sharing similar patterns of consumption, a large part of the resource consumption is determined by households (Biesiot et al., 1999).

Given that households are consuming goods and services, they are interacting with their environment by extracting energy and resources and depositing waste as an output in an indirect as well as direct way. These households are influenced in their structure by values, norms and cultural aspects of society.

Concerning energy consumption different strategies of households for the demand of energy services are emanating through satisfaction of needs. These strategies are determined by a wide range of factors (socio-economic, cultural, lifestyle aspects) manifesting in a differentiation of energy consumption patterns – structure and quantity, quality of energy consuming entities and its patterns of utilization – resulting in varying levels of final energy consumption in the sector of passenger car mobility, public transport and air traffic as explored by this study.

Energy consumption of household mobility is impacting on the environment either directly through combustion of fossil fuels or indirectly through the use of electricity. Its impact on the environment varies in terms of composition of the national energy system. Besides the environmental impacts of household mobility, effects with social implications exist like passenger safety and security, public health, noise and congestion within the transport system which are having an adverse and unevenly distributed impact on human populations.

1.6. Study area location and description

In the next chapters geographic and socio-economic information is provided on the study area in general and especially information on mobility consumption patterns and problems related to transport.

Austria, officially the Republic of Austria (Fig. 3), has a land area of 83.879 km² and is located in the southern part of Central Europe. With its 8.3 million inhabitants and a birth to death ratio being almost equal in 2008 the population has been growing almost exclusively through migration. The following characteristics describe Austria as a developed country.



Figure 3: Map of Europe and Austria, location of research area. Source: designed by author

In terms of GDP per capita Austria is one of the richest countries in the world. Like most advanced modern economies services far outweigh the other sectors of the Austrian economy in terms of gross value added. Around two thirds of the gross value added comes from this sector, about 31 percent comes from the production sector, and only about 2 percent comes from agriculture and forestry. When comparing life expectancies in the EU, Austria is in the top third for men and women combined. In 2006, the median gross annual income of Austrian wage and salary earners totalled € 22.833, with a median net annual income of € 16.918. (Statistik Austria, 2008a)

1.6.1. The Austrian energy system

The Austrian domestic energy system is, for an overwhelming part (over 78 percent), made up of fossil energy, whereby only around 12 percent of the crude oil demand and 21 percent of the gas consumption is fulfilled from domestic sources and its demand for coal is completely dependent on foreign countries. Austria is only self-sufficient in renewable energy sources such as biomass and hydro power. Total energy consumption (gross domestic consumption/GDC) as well as final energy consumption has almost doubled in the last 40 years in Austria. Besides transport, which is the largest area with a percentage of 31.7 percent, indoor heating dominates the energy consumption with 29.0 percent. (Statistik Austria, 2008a)

The trend of final energy consumption partitioned into sectors, which is continuously growing from 1970 to 2008, is displayed in figure 4.

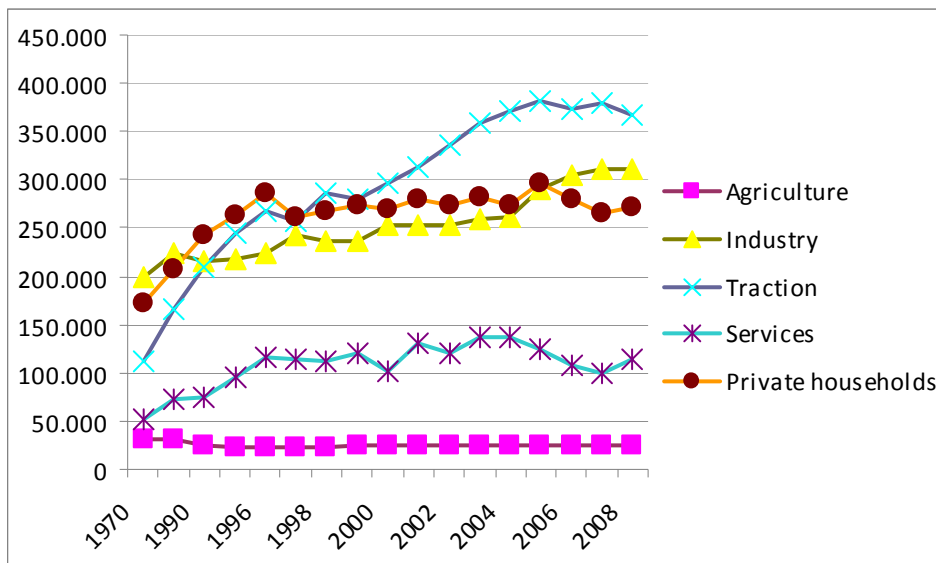


Figure 4: Trend (1970-2008) of final energy consumption (Terajoule) in Austria split up into sectors. The ups and downs of the private households are due to temperature differences in winters. Source: adopted from Statistics Austria, 2008b; designed by author

Since 1998 the most energy intensive sector in Austria is traction (34 percent of total final energy consumption in 2008), which was continuously growing over the last decades, followed by industry (29 percent) and private households (25 percent).

1.6.2. The current situation of the transport sector in Austria

This section provides an overview of current trends in the Austrian transport sector and related energy consumption and emissions. Special attention is given to the area of household mobility patterns if data are available.

According to Anderl et al. (2009) the most important energy sub-sectors in 2007 in terms of green house gas (GHG) emissions were *transport* with a share of 37 percent, followed by *Manufacturing Industries and Construction* (24 percent), *Energy Industries* (21 percent), and “*Other Sectors*” (mainly residential heating – 17 percent). In the sector of transport an increase of GHG emissions of 73 percent due to increased traffic volume has been observed since 1990. Concerning passenger transport for Austria

the BMLFUW (2001) forecasts that volumes will grow by 76 percent by 2030 (from 1990 levels).

Additionally to the increase of traffic volume within Austria, the amount of fuel bought in Austria but driven elsewhere – an effect mainly caused by different fuel prices of neighbouring countries – increased even more. Total emissions from transport increased by 1.1 percent from 2006 to 2007. (Anderl et al., 2009)

However, data on energy consumption in the area of private households are not provided by Anderl et al. (2009). Consequently, this leaves a gap in the data when it comes to further differentiating the origins or key aspects of transport energy consumption and understanding patterns of energy demand in the mobility sector at household level.

The VCÖ is offering comprehensive information about the environmental, social and economic impacts in terms of external costs in an Austrian context.

The total annual estimated external costs of traffic for Austria are 17.5 billion € (Fig. 5) of which a big contingent is due to congestion (7.9 billion €), accidents (3.7 billion €), health (2.0 billion €) and climate change (1.8 billion €).

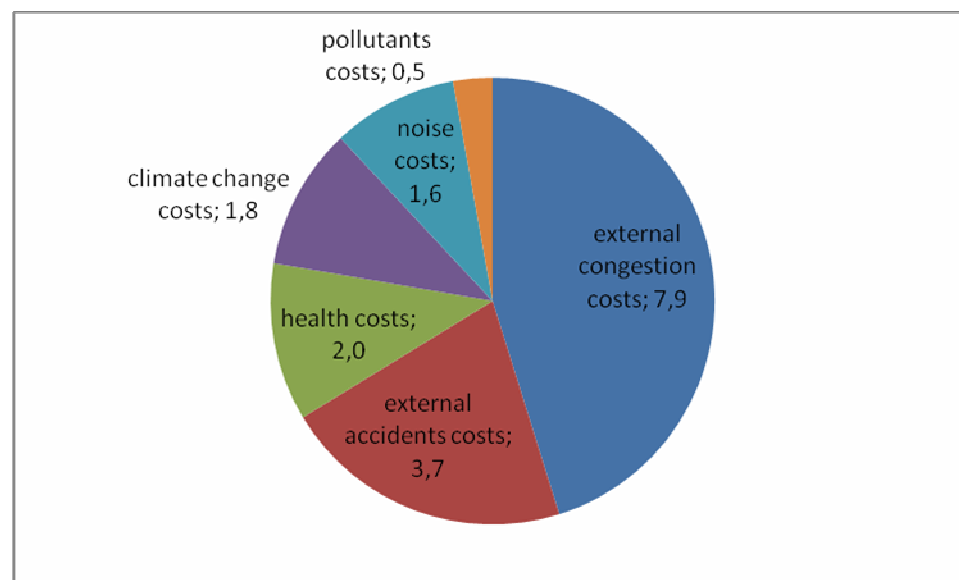


Figure 5: Annual estimated external costs of traffic in Austria (in billion €). Source: adapted from VCÖ, 2007a

Concerning mobility consumption patterns of Austrian households figure 6 indicates that kilometres covered per person measured in billions are depicting a rising trend since the 1950's. A striking increase can be observed in the area of passenger cars (VCÖ, 2003).

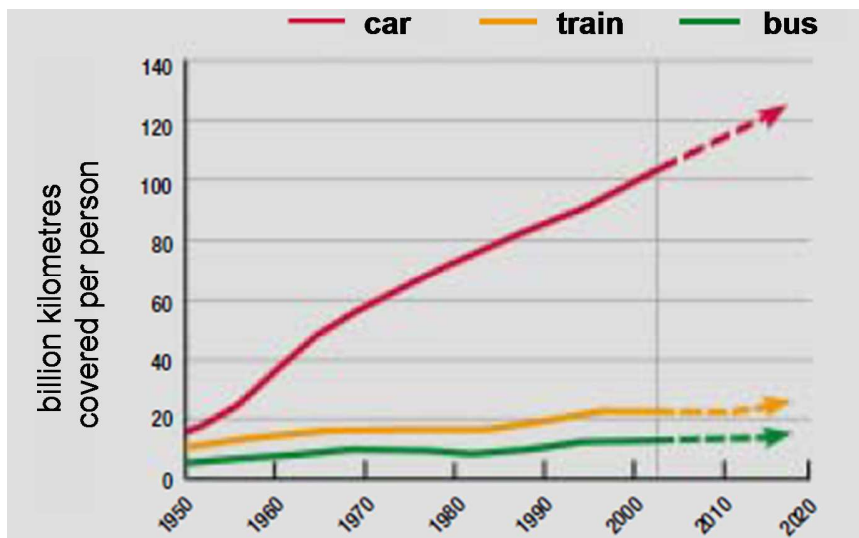


Figure 6: Trend of billion kilometres covered per person differentiated in mode of transport. Source: VCÖ, 2003

Figure 7 is indicating that an energy saving house with a passenger car has a higher total energy demand than a normal house without a passenger car. Consequently this comparison is depicting the importance of mobility consumption patterns of households and its impact on energy demand and forming the concept of traffic saving houses. (VCÖ, 2007b)

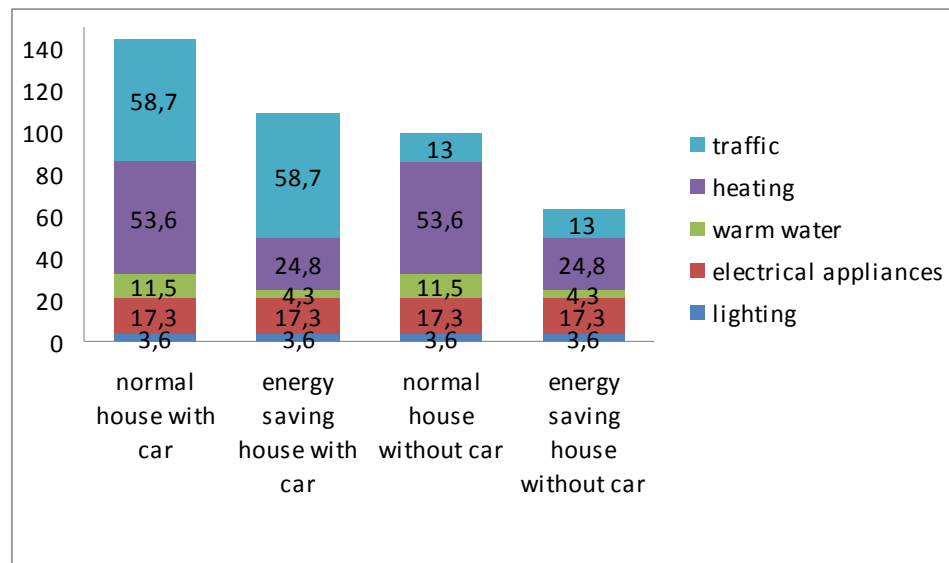


Figure 7: Comparison of energy savings (Gigajoule per year) according to housetyp and car ownership. Source: VCÖ, 2007b

Finally a plurality of aspects like generally high energy demand, external effects, rising trends of consumption and related emissions associated with the issue of household mobility indicates the need for immediate action. However, in order to fully understand patterns of consumption concerning private household mobility one first essential step is the establishment of a comprehensive data base and to identify key drivers influencing consumption.

1.7. Scope of the study

This study concentrates on the characterization of households by socio-economic differentiation. In research a wide array of other approaches are used to elicit household structure and classification by referring to lifestyles and more culturally specific indicators (Schulze, 1992; Karmasin, 2008), which are usually encountered in motivation research. Furthermore, focus is set on the investigation of direct energy consumption in the area of household mobility beside other aspects like heating and electricity.

Apart from a more holistic picture by capturing also the indirect energy requirements of households through the consumption of goods and services (Lenzen et al., 2004) this study investigates the energy demand of private mobility, technical aspects and their patterns of usage. Consequently this

enables an in depth understanding of the underlying factors. However, it is evident that indirect energy requirements emanating from producing facilities and the service sector are ultimately demanded by households or as Adam Smith once observed: “consumption is the sole end and purpose of all production” (Smith, 1776, Volume II, Book IV).

Nevertheless, by displaying and examining the most important parts of mobility in the area of households – passenger car mobility, public transport and air travel – the study is able to capture an integrated view.

1.8. Significance, Challenges and Limitations of the study

According to Bohunovsky & Grünberger (2010), subscribing to the hypothesis that in the context of (domestic) energy use lifestyle can be identified as the main driver, the attempt to explain energy consumption on socio-economic parameters alone is insufficient.

However, in order to enable an in-depth analysis in this study socio-economic data are used providing a comprehensive basis for

- comparing current trends in literature of mobility consumption patterns of households
- offering a widespread analysis on common household characteristics and related energy consumption patterns as insight and guidance for targeting and demand oriented policies
- complementing the analysis on the level of lifestyle aspects

Significance of the Study

The study investigates the mobility consumption patterns of Austrian households by relating energy demand, vehicle inventory and patterns of utilization and socioeconomic data, which is at the time and compared to other scientific efforts in this field a unique approach so far.

The analysis and data of this work might be of substantial importance for the understanding of underlying consumption patterns of households, planning of mobility services and infrastructure and as well for demand oriented and targeting policies.

Challenges of the study

A number of constraints have limited a perfect execution of this study. Due to the wide range of variables collected within the aspect of private mobility the challenge was to identify the most important ones in terms of best characterising household consumption patterns. Since the study focuses on socio-economic aspects it is difficult to assess their explanatory power on household energy consumption patterns without considering or taking into account other influencing factors like cultural and lifestyle aspects.

However, follow-up analysis on drivers of household energy consumption patterns by relating socio-economic, cultural and lifestyle aspects which are either reinforcing or defanging mutually all together might clarify this situation.

Because of the fact that literature on key factors influencing mobility consumption patterns of households is rather scarce the study grounds its assumptions on current information about drivers on energy consumption patterns in general. Consequently mixing drivers of energy consumption in general and of mobility specifically might lead to incongruence about responsible drivers.

Limitations of the Study

In today's post modern society socio-economic aspects for describing consumption patterns are more or less insufficient as more elaborated concepts of lifestyle have been adopted for analysing and mapping these patterns of consumption. These concepts of lifestyles are incorporating values, attitudes, aesthetic preferences, leisure activities and consume-orientated behaviour to the analysis beyond classical criteria as occupation, age and education. However, efforts of quantitative descriptions of lifestyle concepts and their linkage with aspects of energy consumption in the scientific field have been rather neglected or are very scarce (Bohunovsky & Grünberger, 2010).

Energy consumption for mobility aspects is not just a matter of lifestyle, cultural and socio-economic aspects as partly explored by this study. It is also profoundly influenced by technology, transportation policy as well as structural aspects. Therefore a multifactorial effort is needed in order to

provide a holistic approach of understanding the key drivers of household mobility patterns.

1.9. Theoretical conceptual framework

The energy consumption of households is determined by the demand of energy services in general. Fundamental to this approach is satisfaction of needs through energy services in the sector of mobility. The consumption patterns concerning energy use at the level of households responsible for satisfaction of needs is influenced by cultural, lifestyle, socio-economic as well as technical and structural aspects.

The approach described in figure 8 aims at bridging the gap between energy consumption and its related key drivers based on a consumer perspective at the level of households.

By this means not only households' mobility energy consumption has been estimated but also its key drivers meaning socio-economic characteristics like household size and composition, type of education, type of employment, level of income, degree of urbanity etc. The study focuses on factors related to societal structure (technology and lifestyle aspects), which have an impact on the structure and characterization of households and, furthermore, on the volume and composition of consumption patterns.

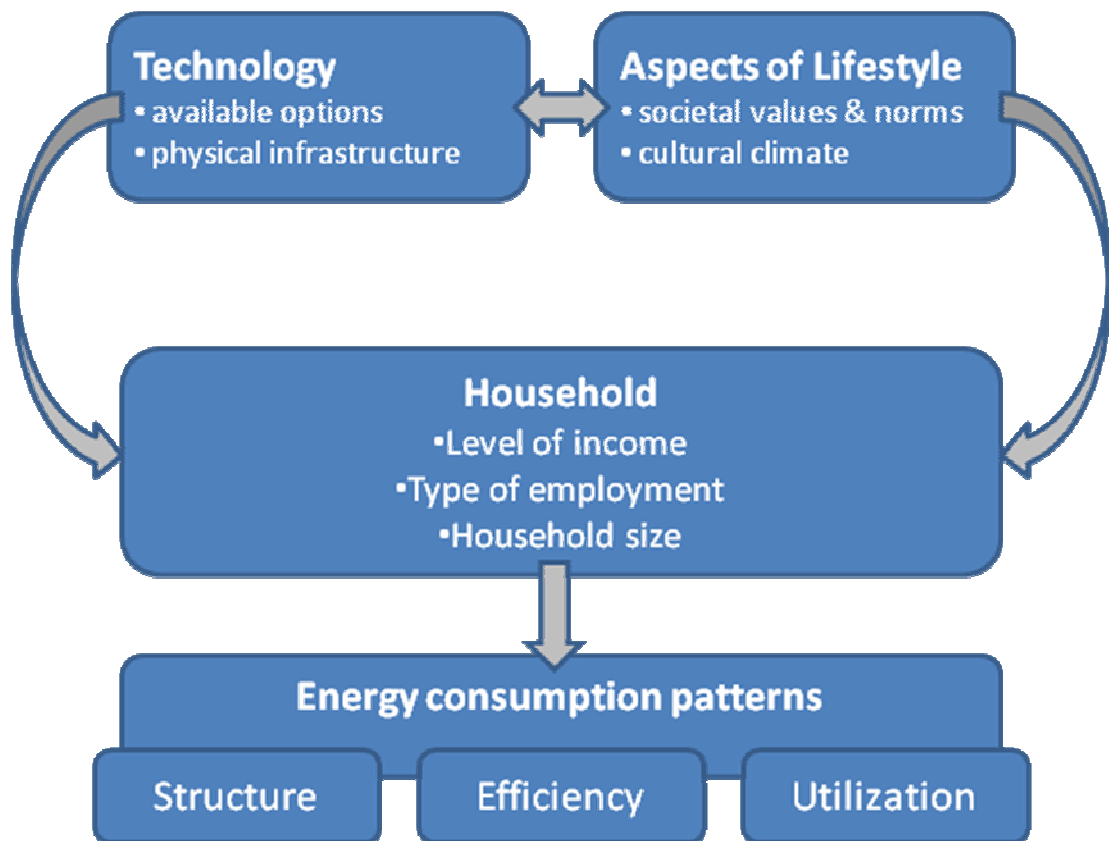


Figure 8: Conceptual framework. Source: designed by author

1.10. Definition of general concepts

Consumption

In the OECD Environment Directorate's Programme on Sustainable Consumption the term *consumption* refers to the consumption of products and services by households. It covers a sequence of activities by households from the selection and use of a product or service through its disposal. 'Consumption' includes consumption of both marketed and non-marketed products and services. (OECD, 2001)

Final Energy consumption

The term final energy consumption refers to the quantity of energy made available to the consumer for transformation into useful energy (Statistics Austria, 2009b).

Private/household mobility

Household mobility comprises the need for three types of mobility: commuting and other work-related mobility, family and civic excursions (shopping, school, medical visits, various meetings, etc.), and social and recreational trips. In order to fulfil these needs distances are covered by passenger car, public transport (bus, train, tramway, metro) and/or airplane regarding the data records and corresponding energy consumption.

Sustainable mobility patterns of households

As stated by Steg et al. (2005) yet no common definition of sustainable transport or mobility has been elaborated, but it is generally accepted that sustainable transport implies balancing current and future economic, social and environmental qualities. In addition, it is generally believed that current traffic and transport patterns are not sustainable in the long term, because of the fact that the negative environmental, social and economic externalities outweigh the social and economic values of transport.

In terms of energy consumption sustainable mobility patterns with regard to the data base under study are defined as patterns with the least amount of equivalent household energy consumption.

Regarding external costs of transport and its relation to sustainable mobility patterns figure 9 shows a clear correlation between traffic costs (share of GDP of corresponding city) and share of covered distances by bicycle, walking and public transport. Hence, suggesting that households covering most of their distances by these modes of transport are significantly reducing their impact in terms of external costs on the environment and social issues and therefore can be characterized as having more sustainable mobility patterns than other households.

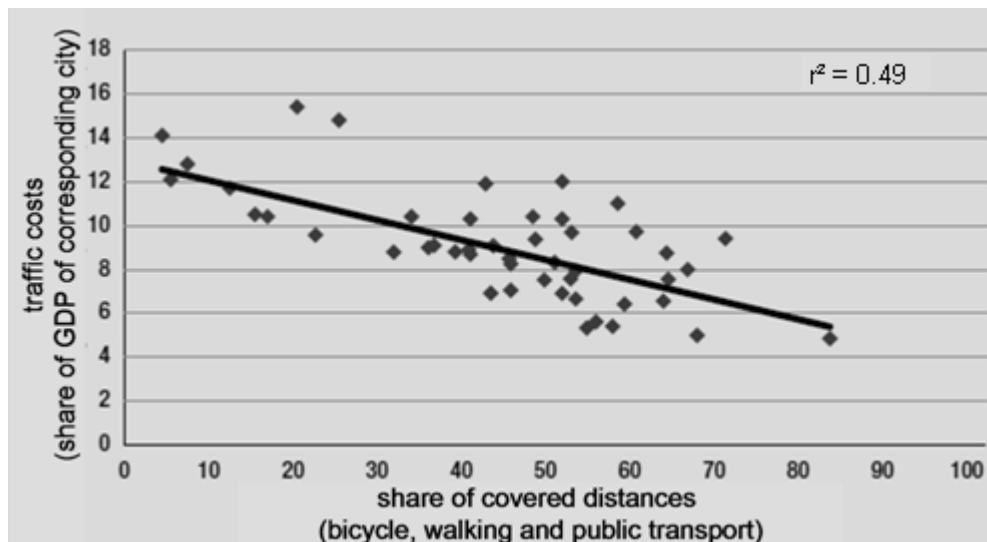


Figure 9: Correlation between traffic costs and share of covered distances. Source: Internationaler Verband für öffentliches Verkehrswesen, 2006, in VCÖ, 2009

Socioeconomic variables/parameters

Socioeconomic variables (age and employment level of reference person, household composition and size, level of education, income, degree of urbanity etc.) comprise a number of indicators which illustrate household structure.

Households

Households can be considered as the smallest social units, consuming a complex and changing mix of goods and services.

1.11. Databases and projects on private mobility consumption patterns

One of the first attempts to set up a Europe wide data base on public opinion and information about special issues like mobility patterns are the Eurobarometer reports. Since 1973, the European Commission has been monitoring the evolution of public opinion in the Member States, thus helping the decision-making and the evaluation of its work. Although very recent and comprehensive studies and surveys are conducted by the EU, the data obtained are more related to opinions towards policies and projects, but are offering little information about inventory or behavioural patterns. Information

is provided in order to give an overview of mobility patterns and individuals are surveyed on more general issues related to EU Transport Policy, including urban transport, environmental and traffic aspects, flight safety and passenger rights. Some of the main findings of the Eurobarometer report of attitudes on issues related to EU transport policies are that the main mode of transport by EU citizens is their car (51 percent), followed by public transport (21 percent), walking (15 percent) and motorbike (2 percent) and that 81 percent of EU citizens have a car in their household. (Gallup Organization, 2007)

Another very important source of information is the Statistics Austria data base which provides reliably collected and expertly analysed political, social and economic information on the national level. Although it offers detailed and comprehensive information of socioeconomic data of households, in most instances it fails to address quantitative data of consumption patterns concerning private mobility differentiated into household types. However, motor vehicle statistics provide substantiated information about both the stock of motor vehicles and registrations of new and used vehicles, annually driven kilometres and fuel consumption differentiated into fuel types, whereas no differentiation into household types have been undertaken (Statistics Austria, 2009a). Besides on the aspect of public transport and passenger car patterns of usage have been evaluated in a comprehensive way by gender, age group, employment status, education, type of municipality, rate of urbanisation and federal states (Statistik Austria, 2009c). Therefore efforts for further socio-economic differentiation of households in the field of private mobility concerning patterns of usage have been undertaken.

ODYSSEE was an international project which provided a database on energy efficiency data & indicators, for the EU-27 members plus Norway and Croatia, offering time-series analysis. This database includes a very detailed set of data & indicators by sector, to assess energy efficiency performance and trends. ODYSSEE data series are macro-indicators on energy consumption by detailed sectors (households, transport etc), prices, carbon dioxide emissions, and related drivers of consumption per sector. Substantial information is provided in the sector of private households and transport

concerning energy consumption, structural data and corresponding drivers. Structural data in the sector of mobility, although not linked to households, give insight into average car stock, change in distance travelled by car in kilometres per year and time series data, which display trends in the specific consumption of cars by country. In the household sector data are apportioned in space heating, water heating, cooking, lightning & electric appliances. Special emphasis is given on drivers influencing energy consumption. (ADEME & Enerdata, 2008; EURIMA 2008) Nonetheless, efforts to associate data of household energy consumption with socioeconomic aspects apart from income and more detailed information of mobility patterns are missing.

Eurostat is a Directorate-General of the European Commission located in Luxembourg. Its main tasks are to provide the EU with statistics at the European level and to promote the harmonisation of statistical methods across the Member states, candidate countries and EFTA countries. Furthermore, it enables the comparison of statistical information between countries and regions. The Eurostat database offers information on the aspect of transport and household's final energy consumption, but does not associate energy consumption with socioeconomic and behavioural aspects. Moreover, data on private mobility are not distinguished in the sector of household's final energy consumption, although household expenditure data per inhabitant are provided as index for transport.

Despite the number of comprehensive and scientific data bases providing information in the area of mobility on the one hand and household's overall energy consumption on the other hand, efforts in order to establish more scientific oriented data bases which are associating technical aspects, their patterns of usage and the socioeconomic variables on the household level are rather scarcely represented.

Reliable current information on both, the socioeconomic characteristics of households and their consumption patterns and styles, are neglected in the context of the Austrian mobility sector. Nevertheless such an analysis might be of considerable importance in the planning of mobility services and infrastructure and as well for demand oriented and targeted

policies. Therefore to compile a data base which is comprehensive and representative of households concerning the aspect of mobility and its energy demand and to investigate the relationship between technical aspects, their patterns of usage and the socioeconomic variables turns out to be a goal that is to achieve.

1.12. Drivers of household energy consumption patterns

Only in the last two decades the political and scientific community shifted its attention towards the consumption side of energy as a start in order to better understand consumer's behaviour. Besides the production side of the economy, which has been investigated in a comprehensive way, the level of households and its consumption activities are becoming more and more the centre of scientific investigation.

Especially energy consumption of households comprises a rapidly increasing part of society's overall consumption until 2020. Concerning OECD by 2020 it is expected to grow by 35 and 51 percent worldwide (Zacarias-Farah & Geyer-Allély, 2003).

Most of the research in the field of energy consumption at the household level in the last decades has been aimed at investigating technical parameters – such as efficient use of energy and final energy demand. The socio-economic and cultural dimensions, which are guiding our actions – in market research often described as lifestyles – have been addressed rather scarcely. Only in the late 1980s the concept of lifestyles has been introduced in the field of personal energy consumption, but in a negligible way (Schipper et al., 1989).

Nowadays research expertise that is focusing on household consumption level and their associated lifestyles including socio-economic and cultural aspects is increasing (Schipper et al., 1989; Schlomann et al., 2004; Lenzen et al., 2004; Moll et al., 2005; Bohunovsky & Grünberger, 2010). Furthermore, it has been acknowledged that establishing the link between concepts of lifestyles to patterns of consumption offers the opportunity in order to respond to consumers adequately, communicate knowledge and innovations effectively and to anticipate the consumption behaviour of citizens (Bohunovsky & Grünberger, 2010). Consequently, this

may lead to a better understanding and investigation of routes to the required reduction of (long-term) environmental impacts of the combined effects of production and consumption activities that take place within the economy (Duchin, 1995).

The next paragraphs provide an overview of past research focusing on lifestyle, cultural and socio-economic aspects influencing household mobility patterns if available and consumption patterns of households in general acting as guidance for further investigation of household consumption patterns in the mobility sector.

While it is widely accepted that societal energy consumption is not only influenced by technical parameters but also by lifestyles, cultural and socio-economic aspects, at the present time consensus about the extent, character and of the influence these variable cast upon energy consumption widely varies (Duchin, 1996).

One of the first studies incorporating aspects of lifestyle was conducted by Schipper et al (1989) in the United States. He concluded that about 45 to 55 percent of total direct and indirect energy use is influenced by consumer's activities for personal transport, personal services, and homes in general and that energy use for mobility especially has been raised by income-driven life-style changes during the last decades. In general Schipper et al. found out that household size and age distribution, the nature of employment, and the degree of urbanization affect the use of energy-consuming goods. Detailed analysis showed that energy use increases more slowly with household size and that small households compared to larger ones use more energy per capita controlling for factors like income, fuel type and other aspects. Furthermore, Schipper et al. already projected that this relationship matters greatly given the worldwide trend towards smaller households. Therefore the shrinking households emerge as a profound driver of household energy use in the future. Concerning car possessions elderly singles own fewer cars and drive considerably less than others culminating in lower energy use in transport. Schipper et al. also indicated that car kilometres increase with age and then fall for both men and women in the later stage of their lives. Big differences in per capita energy use reflect

differences in household composition. Schipper et al. reported a trend that single-person households, households consisting of unrelated persons, single-parent households, and elderly households are increasing. These households will raise per capita energy use in households and transport profoundly in future. In contrast the typical family with children (married parents, 2.1 children) uses the least energy per capita and comprises a declining share.

Biesiot et al. (1999) explored that lifestyle and socio-economic parameters differ in structure and function and therefore have different impacts on the metabolism of a household in the Netherlands. The study shows that there exists a linear relationship of expenditure and energy requirements. Furthermore, significant differences have been found between single-person households and multi-person households. Although its substantiated efforts in time series analyses and comprehensive data base (400 households) the study did not identify any driving forces and differences in household consumption patterns beside expenditure and household size.

According to Dziubinski et al (1999) disparities in household energy use exist due to disposable income of households as well as cultural preferences. The trend of increase in energy-based living standards due to increases in household income and the opposing trend of changing consumption behaviours and energy efficiency gains are determining household energy consumption since the 1970s.

A more recent study conducted by Lenzen et al (2004), which examined energy use of Sydney households, indicated the correlation between energy use and income, household size, age, and degree of urbanity. By using structural path analysis it has been demonstrated how significant differences, especially in the sector of mobility (direct and indirect automotive fuel consumption and air travel), in lifestyles between inner and outer areas of Sydney leads to different energy use characteristics. By using multivariate statistics Lenzen et al. described age as a socio-economic variable having the strongest influence on energy required for mobility in particular automotive fuel consumption, closely followed by degree of urbanity. Moreover, a high correlation has been found between public transport energy use and income and consequently for level of employment.

In addition, an analysis controlling for the factor of income showed that household lifestyles can vary significantly in their energy requirements.

A more recent study from Germany by Schlomann et al. (2004), who investigated household energy consumption in the sector of mobility and found a correlation between number of cars and household income and number of persons respectively.

The “Verkehrsclub Österreich” (VCÖ) is exploring issues of mobility in Austria. As a NGO it is providing knowledge for a fair transport policy which is offering equivalent mobility opportunities irrespective of age, income, and health and keeping human impact on the environment through mobility at a low level. The VCÖ (1999) is reporting that with ascending age (45 years old until 85 and older) the share of car usage of total covered distance is decreasing heavily from 47.3 percent to 2.2 percent for the 85+ generation. In contrast the share of public transport of total covered distance is increasing with ascending age from 10.7 percent to 15.2 percent. Information is provided about car possession of Austrian households (VCÖ, 2003; Fig. 10). 47 percent of households have at least one car and a share of 37 percent of households either does not possess cars or a driving license.

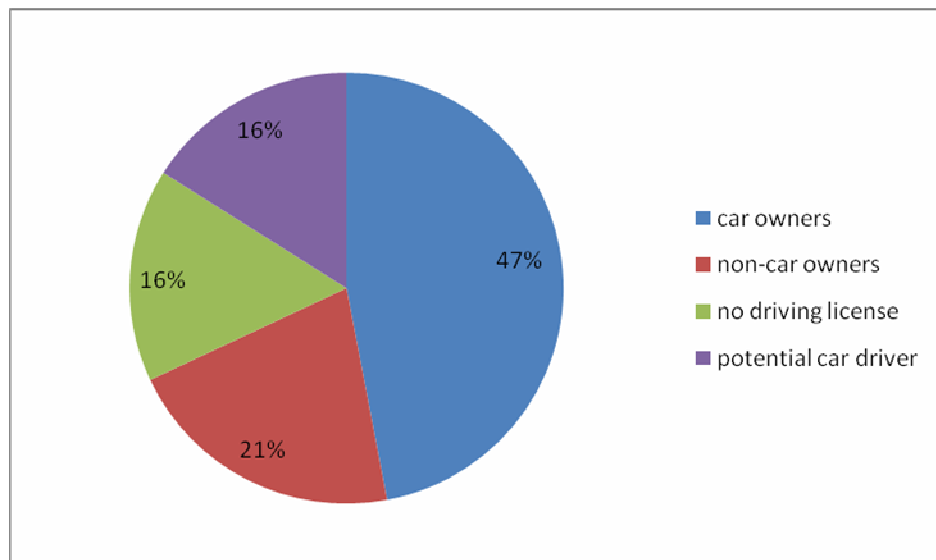


Figure 10: Percentage of households: 47 percent car owners, 21 percent non-car owners, 16 percent no driving license, 16 percent potential car drivers. Source: adapted from VCÖ, 2003

The VCÖ (2009) is providing data on multimodal mobility meaning alternate usage of transportation systems by a person over a specific period of time and showed that with a decreasing degree of urbanity the share of public transport on multimodal mobility is decreasing (4.8 percent of total distances travelled are covered by bus or train). Furthermore as stated by the VCÖ (2009) and estimated in a study by Herry Consult GmbH (2007) the share of cars in multimodal mobility (Fig. 11) in Austria will decrease significantly until 2020, from 48 percent in 2007 to 38 percent in 2020, and the share of public transport will increase from 17 percent in 2007 to 21 percent in 2020.

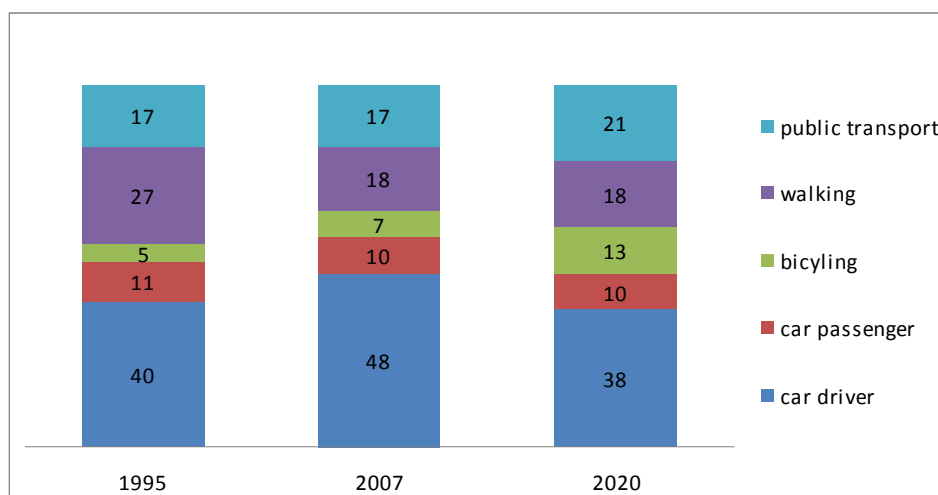


Figure 11: Share of covered distances by means of transport (trend for 2020). Source: adapted from VCÖ, 2009

In addition, the VCÖ (2009) found gender differences in kilometres travelled per day and patterns of usage for public transport, indicating that men travel more kilometres per day than women and use public transport less often.

According to Moll et al. (2005) – using the approach of household energy metabolism in a cross-national comparison study between United Kingdom and the Netherlands – the most important determinant explaining household energy requirements is the average level of household expenditure (or income). For the lower and higher income classes of households, the share for motor fuel, transport, and recreation together is

less than 20 percent and respectively 25 to 35 percent. They also observed that in urban areas direct energy use, especially for motor fuels, is lower than in the corresponding national average data. Comprehensive analysis has been provided for each family phase. For example, pensioner households have relatively low energy requirements for the categories of transport, recreation, and motor fuels, whereas single and two-adult households and households with two adults and children have very high energy requirements for recreation, transport, and motor fuels.

A study done by Abrahamse & Steg (2009) in the Netherlands showed that direct and indirect energy use of households is positively associated with both income and household size whereby both explained 23 percent of the variance of household energy use.

In conclusion, the previous paragraphs showed that energy consumption in general and its drivers have been mostly investigated in terms of total energy consumption without drawing attention on the aspect of mobility at all or only in a negligible way. In summary this brief overview shows that drivers of household consumption are manifold and varying in their influence.

2. Materials and Methodology

2.1. Data sources

Both, quantitative and qualitative data have been collected from secondary sources. The purpose of data collection was to provide a comprehensive picture of drivers of household energy consumption patterns in literature.

A critical literature survey was done to gather information on energy consumption patterns of households. A variety of data sources including research publications, reports from different institutions and organizations were gathered in order to establish relevant past and current information on consumption patterns of households in general and in the area of private mobility. Articles from different journals and internet sources were also consulted, in order to build up an idea of what has been done or investigated so far about socio-economic aspects determining mobility consumption patterns of households.

The data base analysed in this study have been collected within the project SEU by SERI (Bohunovsky & Grünberger, 2010) funded by the “Klima und Energiefonds”.

2.2. Research project: Styles of energy use

The Sustainable Europe Research Institute (SERI) is currently working on a research project (Bohunovsky & Grünberger, 2010) funded by the “Austrian Klima- und Energiefonds” (<http://www.energisch.at>) in order to establish a substantiated data base, which associates the demand of energy services in Austrian households to socio-economic, cultural and lifestyle aspects (<http://www.energisch.at>).

The project is aiming at the conception of Styles of energy use (SEU) in Austria. Therefore the concept of “Erlebnismilieus” (social milieus of experience) by Schulze (1992) has been used. This concept, often used in motivation research has been adapted and validated for the Austrian context by Karmasin (2008) and has been used in this project by relating household energy consumption to aspects of lifestyle.

Data on socioeconomic, cultural, technical aspects, their patterns of usage and respectively final energy demand have been collected in a representative survey of 1014 Austrian households. The purpose is to provide a current and comprehensive data base on energy consumption, behaviour and its drivers and most influential factors in order to come up with a detailed and quantitative description of SEUs.

These empirically validated SEUs shall provide insight into the energetically relevant behaviour of the Austrian population, and improve future communication of innovations and the design of energy services, as well as support policy making for a sustainable development of the Austrian energy system (Bohunovsky & Grünberger, 2010).

2.3. Database

The following paragraph provides an overview of the survey in general and of the data structure which is analysed in this study.

Within the project SEU 1014 households have been sampled in a representative way covering all sectors of private energy demand (electricity, heating, mobility). In general the energy demand was calculated by including items like technical entities (e.g. number and efficiency of cars), but also behavioural aspects (e.g. kilometres driven per year). The survey took place in May and June 2008.

Within thematic topics of household mobility the questionnaire included questions according to the three dimensions of changing energy behaviour, questions related to energy consumption are clustered into

- **structure:** quantity of energy consuming entities (e.g. number of cars)
- **efficiency:** quality of energy consuming entities (e.g. fuel consumption of the car(s))
- **usage:** type and frequency of utilization (behaviour, e.g. frequency and types of public transport used, kilometres driven per year)

The calculation of energy consumption in the area of passenger car, public transport and air travel will be explained in the following section.

Passenger car energy consumption has been measured by using the energy equivalent of petrol and diesel fuel respectively and fuel consumption calculated through the use of driven kilometres per year and fuel efficiency. This calculation has been conducted for each car in the household and finally summed up as total energy consumption of passenger cars in the household. In the case of public transport energy consumption households have been surveyed for frequency of utilization and the use of the four different public transport modes: bus, tram, metro and train. This information together with average driven kilometres per mode of transport and energy intensity has been multiplied by household size. Regarding air travel frequency of utilization and preference of short or long haul flight were the main criteria for estimating energy consumption.

In calculating the mobility energy consumption of households the survey solely based its calculations on qualitative estimations of the respondents. Consequently the data on energy consumption in this study are approximations derived from the calculation of data based on qualitative estimations of respondents.

The tables (tab. 1 and tab. 2) below provide an overview of the variables collected within the SEU project and used for statistical analysis in this study.

Table 1: Energy consumption variables utilized in the study

Abbreviation	Description
e_car_total	Total energy consumption of passenger cars per year (kWh/a); text abbreviation: <i>energy consumption of passenger cars</i>
n_car	Number of cars in the household; text abbreviation: <i>number of cars</i>
q_car	Average fuel consumption per car (l/100 km); text abbreviation: <i>fuel efficiency</i>
u_car	driven kilometres of passenger cars (km/a); text abbreviation: <i>utilization of cars</i>
e_pt	Total energy consumption of public transport per year (kWh/a); text abbreviation: <i>energy consumption of public transport</i>
e_air	Total energy consumption of air travel per year (kWh/a); text abbreviation: <i>energy consumption of air travel</i>

Table 2: Socio-economic variables utilized in the study

Abbreviation	Description
size	Number of household members; text abbreviation: <i>household size</i>
n_child	Number of children in the household aged below 14; text abbreviation: <i>number of children</i>
age	Age of reference person; text abbreviation: <i>age</i>
urb	Degree of urbanity measured in size of city; text abbreviation: <i>degree of urbanity</i>
edu	Highest completed education of reference person (1 compulsory school, 2 professional school, 3 secondary school without general qualification for university entrance, 4 general qualification for university entrance, 5 university degree); text abbreviation: <i>education</i>
inc	Monthly after tax household income; text abbreviation: <i>household income</i>

However, the variables education and age are not necessarily representing the socio-economic dimension of the household, since these variables are attributes of the interviewed person. Instead, they give an indication about the characterization of the corresponding household and can still be regarded as a socio-economic driver, because of the fact that 87.5 percent of the interviewed persons stated that they are responsible for decisions regarding consumption patterns either stand-alone or together with a second person in the household. Therefore in the results section, the analysis assumes that the characteristics education and age of the reference person were comparable with the other household members and can be quoted as household variables.

2.4. The household approach

Through manifold daily decisions – what goods and services to buy and how they use them and their decisions on where to live and work, what kind of dwelling to have, how to manage their waste and where to go on

vacation – households are impacting on the environment. When comparing these impacts to the industrial and public sector they seem to be rather minor. However, the combined impact of all households is an important contributor to a number of environmental problems (Zacarias-Farah & Geyer-Allély. 2003).

Zacarias-Farah & Geyer-Allély concluded that environmental impacts from household consumption, highly influenced by lifestyle aspects, are set to grow in these areas over the next 20 years (Fig. 12). Travel and energy use are two of the fastest growing sectors.

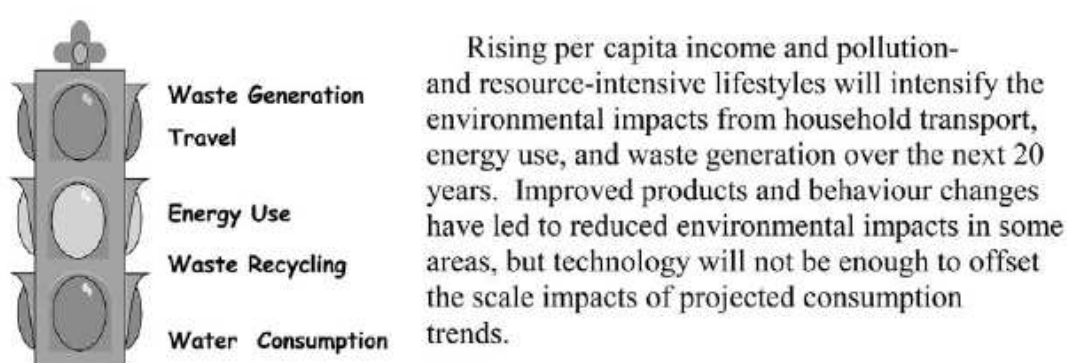


Figure 12: Household environmental impacts to 2020. Source: Zacarias-Farah & Geyer-Allély, 2003

Regarded as being of high political importance the Commission on the Measurement of Economic Performance and Social Progress (Stiglitz, E., Sen, A., Fitoussi, JP., 2009) recommended that trends in citizen's material living standard and consumption patterns are better followed by emphasising the household perspective.

According to Schipper et al. (1989) the household is the most important unit to consider when it comes to energy matters, because most energy-using goods in homes or on the road are shared by several household members.

Changes in household size and age distribution, the nature of employment, and urbanization affect the use of energy-consuming goods (Schipper, 1996).

Since the major part of consumer activities takes place within households, a large part of resource consumption is determined by households rather than individual consumers (Biesiot et al., 1999). Furthermore, this study deals with the concept of households as being social entities with internal and external interactions, which is opposed to the idea of the atomic consumer.

As stated by Weber & Perrels (2000) the choice of households as the main unit under investigation has the three following reasons:

- private consumption is the largest demand category in most economies and hence consumption of households is eventually the main driver for the volume and assortment of commodities produced;
- a detailed analysis of household consumption patterns provides increased possibilities to account for the effects of noneconomic influences on energy use;
- at a conceptual level both economic mainstream and the self understanding of modern democracies postulate the consumers/citizens to be the ultimate sovereign.

2.5. Methods of data analysis

Data was edited, coded, tabulated and analysed by using PASW 17.0 and Microsoft Excel. Data and information gathered were then summarized; statistically synthesized and cross-tabulated in meaningful way for the test of significance among various responses and variables to answer the research hypothesis.

Various statistical models have been used for interpretations and in the test of relationships among variables based on the research objectives. Descriptive statistics was used to provide information on distribution and obtain summary comparisons of certain variables – covering aspects of structure and quantity of energy consuming entities, quality of energy consuming entities and style and frequency of utilization – among socio-economic characteristics of households.

Frequency distribution tables and mean graphs

The utilization of graphs is useful in providing an overview of the data structure of the socio-economic variables by indicating the corresponding factor levels.

Displaying data like car possessions, utilization of public transport and energy consumption and its relation to socio-economic variables (for example passenger car energy consumption and income) on graphs and tables are best for providing an overview of mobility consumption patterns.

Factorial Analysis of Variance

The Factorial Analysis of Variance (factorial ANOVA) procedure can be used to test the hypothesis whether or not the means of two or more groups are not significantly different. With a multi-factorial design two or more independent variable can be assessed in order to test for effects between independent variables and the effects on the outcome variable. Post hoc tests, contrasts and pairwise multiple comparisons are useful in describing the nature of the group differences.

Multivariate Analysis of Variance

Multivariate Analysis of Variance (MANOVA) is a test statistic exploring the relationship between the outcome variables and detecting group differences along a combination of dimensions of two or more dependent variables. Because of the fact that MANOVA incorporates information about several outcome variables it essentially informs whether objects can be distinguished by a combination of scores on several dependent variables.

Discriminant Analysis

As a follow up analysis discriminant analysis has been chosen to be performed after a MANOVA design which was assessing the relationship between the dependent variables. Discriminant analysis offers a vital way in order to explore the nature of these relationships and hence identify one or more linear combinations of dependent variables (discriminant function variates) that best define differences across the dependent variables. This

follow up analysis has been preferred instead of separate ANOVAs because it keeps the main purpose of MANOVA by embracing the relationship between the different dependent variables and therefore essentially reflecting the theoretical dimensions.

2.6. Procedure of statistical analysis

The following chapter explores the relationship between energy consumptions patterns and socio-economic factors by using methods of statistical analysis. MANOVA and ANOVA were performed to test the hypotheses. To this end the study analyses passenger car, public transport and air travel consumption patterns of households and its associated socio-economic factors in sequence.

The detection and removal of outliers is an essential first step towards a less biased sample. By standardizing the data with z-transformation of the variable of interest values have been detected which were lying outside the confidence interval ($\alpha = 5$ percent).

At first Kolmogorov-Smirnov (K-S) and Levene's tests were applied in order to check the assumption of normality and homogeneity of variance necessary for subsequent statistical analysis. A violation of homogeneity of variance by the factor variables within the three dependent variables of energy consumption (passenger car, public transport and air travel) resulted in the transformation of these variables by means of natural logarithm. However, the limitation of the K-S test is that in large samples, as it is the case in this thesis, significant results are very likely when only small deviations from normality have been recorded. Consequently the K-S test statistics have been analysed in conjunction with histograms and Q-Q chart plots in order to get a more informed decision on the normality of data. However, as Rasch & Kubinger (2006) concluded only severe deviations from normality advice the application of non-parametric tests. Thus, ANOVA was performed if these further analyses proofed the assumption of normality despite the significant result of the K-S test.

In the second step the study measures by using multi-factorial ANOVA designs the interaction effects of the socio-economic variables and the effect of socio-economic variables on energy consumption.

One-way ANOVA designs have been performed solely on the corresponding factor without considering any effects between other socio-economic variables, if transformation of data was not sufficient to deliver the assumption of homogeneity of variance across all factors. Nevertheless, effects of interactions in the multi-factorial ANOVA design might contradict the non-significant effects in the unifactorial ANOVA design. Because of the fact that the variance in a one-way ANOVA design is not broken down into parts of variance that can be explained solely by the incorporated factor variables as it is the case for multi-factorial designs, the analysis in one-way ANOVA should be interpreted with careful consideration. This issue will be dealt with in the further analysis. However, one of the advantages of one-way ANOVA compared to multi-factorial designs using transformed data is the assessment of group differences in absolute and non-transformed terms.

As a post hoc procedure Bonferroni's and Games-Howells test, if violation of homogeneity of variance can be assumed, have been preferred because generally the number of compared means is small and the group sizes are quite different.

In the final step of the analysis the level of aggregation has been reduced by compartmentalising energy consumption patterns into its underlying dimensions – structure, efficiency and usage variables – correlating them with socio-economic variables.

A MANOVA test statistic has been conducted by investigating the relationship between passenger car, public transport and air travel energy consumption in order to account for a more comprehensive and integrated approach of mobility energy consumption patterns of households. A follow up discriminant analysis was carried out in order to identify one or more linear combinations of dependent variables that best defining differences in energy consumption across passenger car transport, public transport and air travel.

3. Results

3.1. Socio-economic variables: descriptives and frequency distribution

The following figures are providing an overview of the data structure and the distribution of socio-economic variables in the data base. The graphs are specifying the different levels of the socio-economic variables, respectively the factor variables used for grouping in the analysis (see table 2, p. 34):

- number of household members
- number of children in the household aged below 14
- household types
- age of reference person
- degree of urbanity measured in size of city
- highest completed education of reference person
- monthly after tax household income

Figure 13 is indicating that single, two person and three person households constitute 81 percent of the data base, while two person households being the most frequent type.

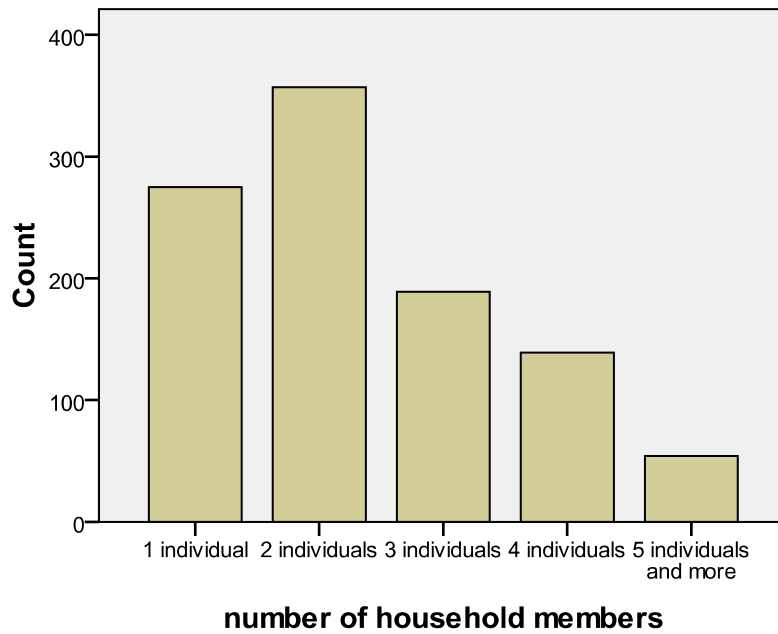


Figure 13: Distribution of individuals living in a household

The distribution of number of children aged below 14 is shown in figure 14. In 76.5 percent of households are living no children, whereas only 8.8 percent have two and more children below 14.

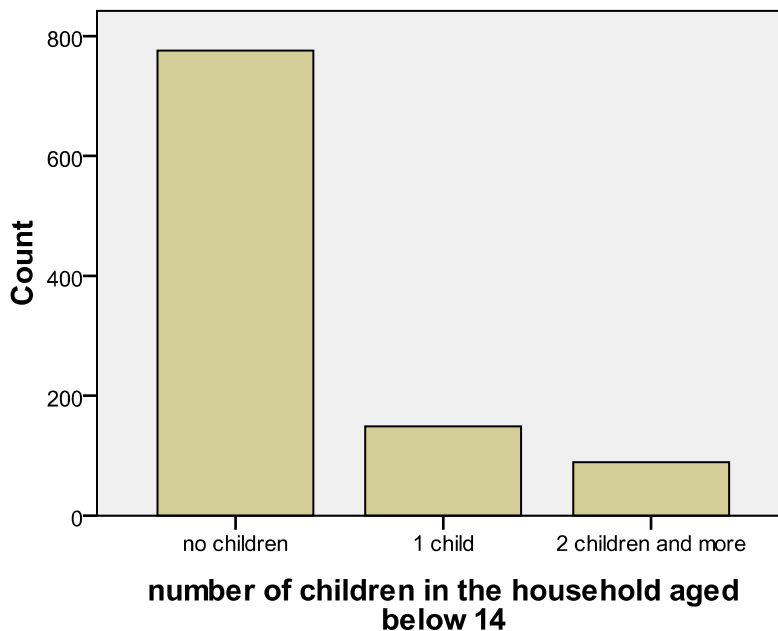


Figure 14: Distribution of number of children aged below 14

Concerning the distribution of different household types multi-person households without children below 14 are the majority of households covering about 50 percent of the data, followed by single woman, single man and multi-person households with one child amounting to about 13.5 percent each (Fig. 15). However, this variable has not been included in the analysis.

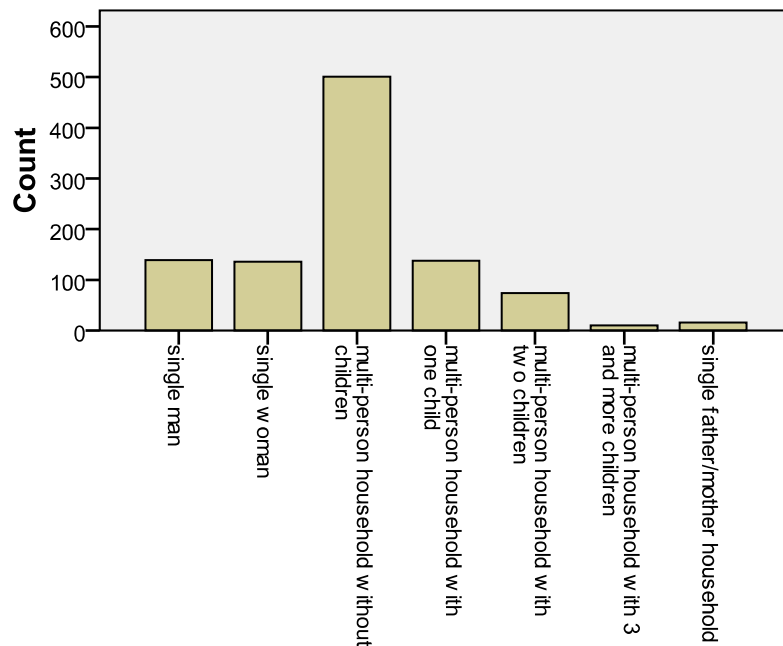


Figure 15: Distribution of different household types

Gender distribution, depicted in figure 16, shows that 48 percent of the sample constitutes a male reference person (the person in the household which is mainly responsible for decisions) and 52 percent a female reference person. However, this variable has been excluded in the analysis.

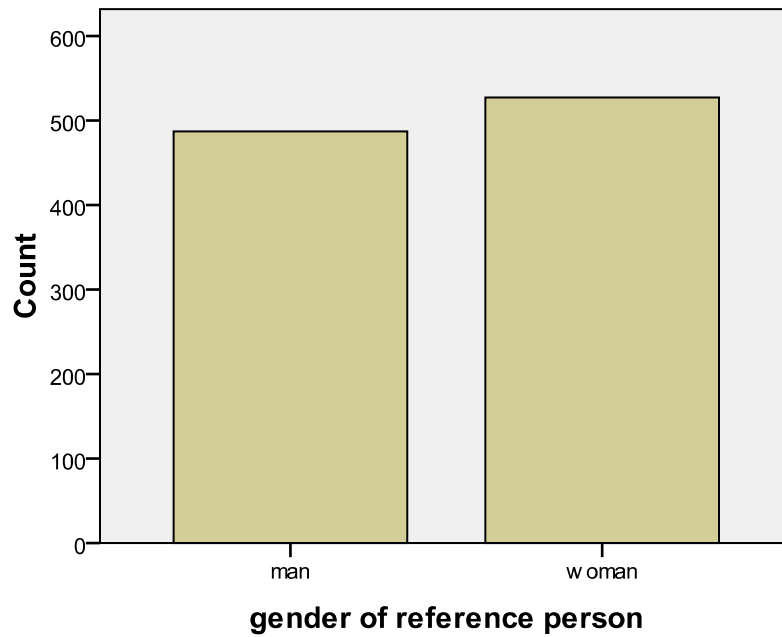


Figure 16: Distribution of gender

Figure 17 indicates that approximately 50 percent of the households live in cities with up to 5000 inhabitants, whereas 10 percent live in cities over 50 000 inhabitants and 20 percent are living in the capital Vienna.

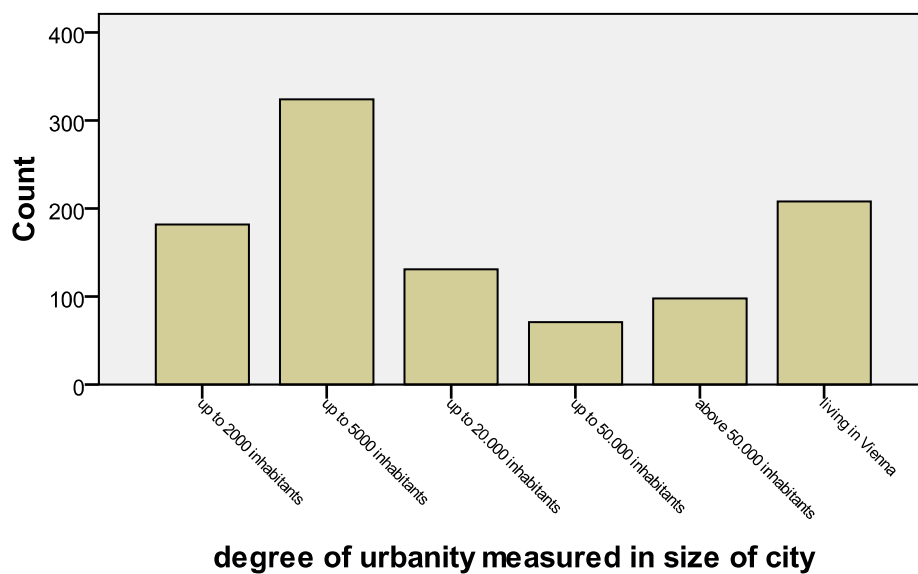


Figure 17: Distribution of degree of urbanity

As shown in figure 18 up to 50 percent of the reference persons have professional school as their highest level of completed education. Approximately 6 percent have graduated from university.

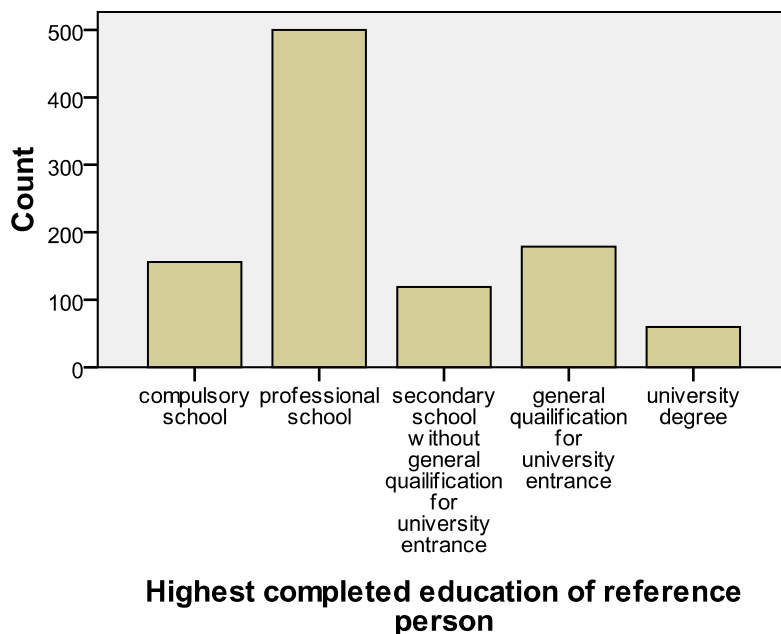


Figure 18: Distribution of highest completed education

The following figure (Fig. 19) depicts the distribution of age of the reference person with the most frequent interval covering the age between 40 and 44 years, closely followed by 45 to 49 and 35 to 39.

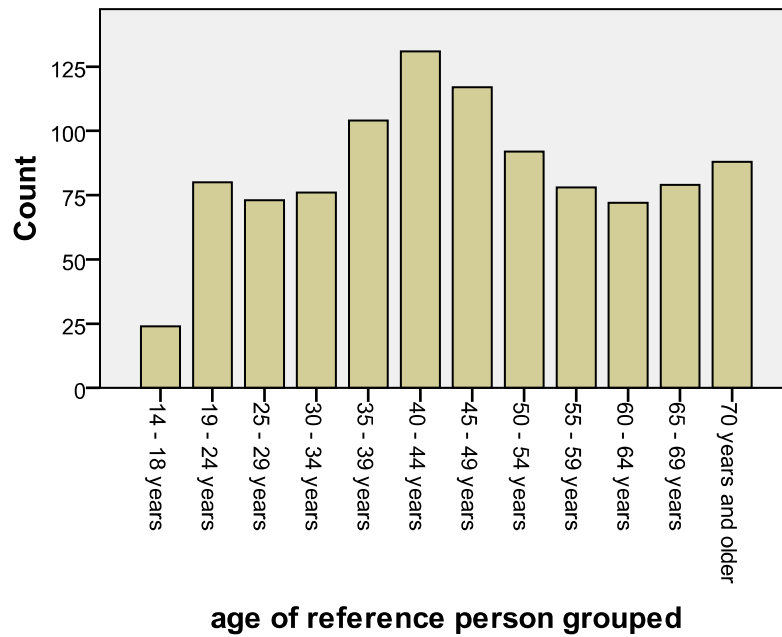


Figure 19: Distribution of age of reference person

Figure 20 indicates the distribution of the monthly after tax household income partitioned into five categories. The most abundant category is income between 1050 € and 2099 € covering about 35 percent of the data, closely followed by the category 2100 € to 2999 € monthly after tax household income.

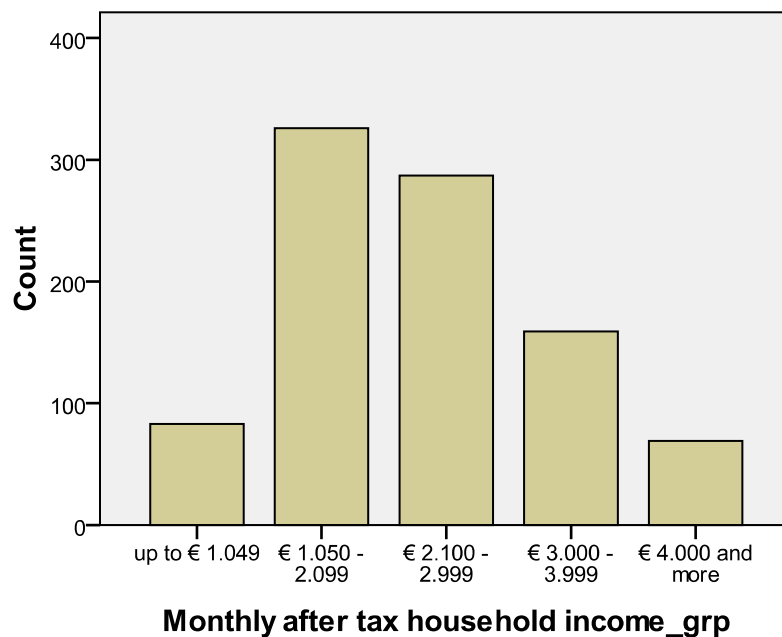


Figure 20: Distribution of monthly after tax household income

3.2. Factors related to passenger car consumption patterns

This chapter is dealing with the relationship between and the effect of socio-economic variables on passenger car energy consumption patterns.

Multi-factorial ANOVA has been conducted in order to account for the interaction between socio-economic variables and extract the exclusive effect of each factor on energy consumption of passenger cars and the interaction between them.

In the following step the underlying dimensions of passenger car energy consumption, their relationship with socio-economic variables and associated impact on energy consumption has been elaborated in a multi-factorial ANOVA design.

The application of one-way ANOVA designs examines the differences of passenger car energy consumption in the various levels of socio-economic variables by using specific constellations of analysis (planned contrasts and post hoc tests).

Preliminary data analysis and preparation

After the detection of outliers 17 data units have been excluded from further analysis, since absolute z-scores have scored above 1.96.

Second K-S and Levene's tests have been conducted in order to test for normal distribution and homogeneity of variance of passenger car energy consumption within the factor variables:

- household size
- number of children
- age
- degree of urbanity
- education
- household income
- number of cars
- utilization of cars
- fuel efficiency

According to K-S test statistic the dependent variable energy consumption of passenger cars was not normally distributed at least in one level of each of the variables listed above and used for later analysis. However, the Q-Q plots indicated a small but not substantial deviation from normality.

For passenger car energy consumption the variances were not equal for the factor variables household size, age, education, household income, number of cars, utilization of cars and fuel efficiency. Instead the variances of the factor variables number of children and degree of urbanity were not significantly different.

Therefore a data transformation has been applied to the abovementioned variables in order to account for the interactions of these variables used in multi-factorial ANOVA designs. After the transformation procedure by using the natural logarithm Levene's test statistic got a non-significant result for all factor variables excepting number of children, age of person and number of cars. However, these variables have been considered in separate one-way ANOVA which is more robust in terms of violations of homogeneity of variance in order to specify the extent of variation of energy consumption in absolute terms within the various factor levels.

Interaction among socio-economic factors and its associated impact on passenger car energy consumption

A four-way ANOVA of passenger car energy consumption has been run on PASW Statistics with the variables household size, degree of urbanity, education and household income.

The ANOVA test statistic reports that there was a significant main effect of household income ($F(4, 453) = 5.81, p < 0.001, \eta^2 = 0.05$) and household size ($F(4, 453) = 2.87, p < 0.05, \eta^2 = 0.03$) on passenger car energy consumption, although the size of the impact is considerably low. On the other hand there was a non significant effect of degree of urbanity ($F(5, 453) = 0.51, p = 0.842, \eta^2 = 0.01$) and education ($F(4, 453) = 0.84, p = 0.5, \eta^2 = 0.01$) on passenger car energy consumption.

This indicates that only household size and household income are impacting on the scale of passenger car energy consumption, whereby the

degree of urbanity and education are not contributing to the amount of energy consumed by passenger cars in households.

Nevertheless, the overall effect of education on energy consumption in the one-way ANOVA (as described in the later section) contradicted the non-significant effect in the four-way ANOVA design. Because of the fact that the variance in a one-way ANOVA design is not broken down into parts of variance that can be explained solely by the incorporated factor variables, as it is the case for multi-factorial designs, the analysis in one-way ANOVA should be interpreted with careful consideration. Concerning post hoc procedures the analysis revealed that the differences in factor levels across all socio-economic variables except for education and degree of urbanity have been the same as for the separate one-way ANOVA procedures and therefore the differences in absolute terms are even valid without considering interaction effects.

However, none of the interaction results revealed a significant effect indicating that the socio-economic variables in combination are affecting passenger car energy consumption.

Correlation among socio-economic and underlying dimensions

Based on previous findings the level of aggregation has been reduced by compartmentalising passenger car consumption patterns into its underlying dimensions – number of cars, fuel efficiency and utilization of per car – and correlating them with socio-economic variables

To this end a correlational analysis was carried out in order to assess the relationship between socio-economic variables and underlying patterns of consumption.

The table 3 shows the most important correlations which have been set up in order to test for specific hypotheses.

Table 3: Correlations between socio-economic variables and underlying dimensions of passenger car consumption patterns

	number of cars	fuel efficiency	utilization of cars
household size	0.44***	-	0.35***
degree of urbanity	-0.18***	-	<i>ns</i>
household income	0.47***	0.12**	0.45***

Household size showed a significant relationship with number of cars and utilization of cars, whereas the correlation between size and number of cars was moderate. Degree of urbanity correlated with to number of cars in a negative, although the strength of this correlation is rather low. Household income indicated both a moderate correlation with number of cars and utilization of cars. However, these results have to be analysed with careful consideration, since these correlations do not state any contributions to the amount of passenger car energy consumption.

Explaining passenger car energy consumption by socio-economic factors and underlying dimensions

The next section addresses passenger car energy consumption by analysing and contrasting the differences between the various levels of socio-economic variables. Planned contrasts and post hoc test procedures have been set up to test specific hypotheses, whereas contrasts have been preferred due to greater statistical power. To this end separate one-way ANOVA designs have been conducted on each of the socio-economic variables. One of the advantages over multi-factorial ANOVA design, where data transformation was a necessary analytical step, is the explicit statement of absolute values regarding energy consumption despite its provision for effects of interaction among socio-economic variable.

Passenger car energy consumption and number of cars

Regarding the one-way ANOVA there was a significant linear trend ($F(2, 82.45) = 117.54, p < 0.001, \omega = 0.54$) indicating that as the number of cars increased, passenger car energy consumption increased proportionately (Fig. 21). A planned contrast showed that energy consumption significantly increased ($t(40.74) = -3.37, p < 0.01, r = 0.47$) with a mean difference of 3934 kWh per year when households with two cars have been compared with household of more than two cars. However, as post hoc tests showed the mean difference of passenger car energy consumption between one and two passenger cars was higher ($p < 0.001$) than the mean difference between households with two cars and households with more than two cars.

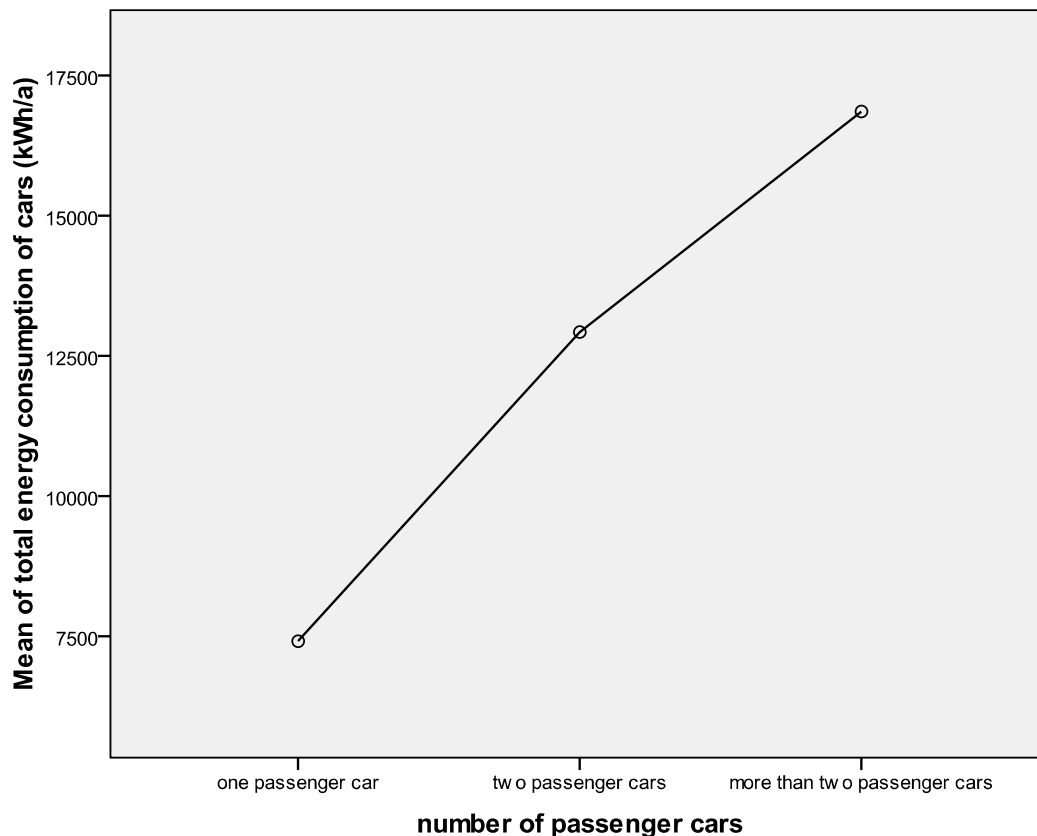


Figure 21: Mean of total energy consumption of cars apportioned from number of cars

Passenger car energy consumption and fuel efficiency

A significant effect of fuel efficiency on passenger car energy consumption ($F(4, 252.08) = 25.87, p < 0.001, \omega = 0.35$) has been observed, indicating that as the fuel efficiency increased, energy consumption increased proportionately (Fig. 22). Furthermore post hoc tests revealed that energy consumption of passenger cars is increasing proportionately to decreasing fuel efficiency of cars.

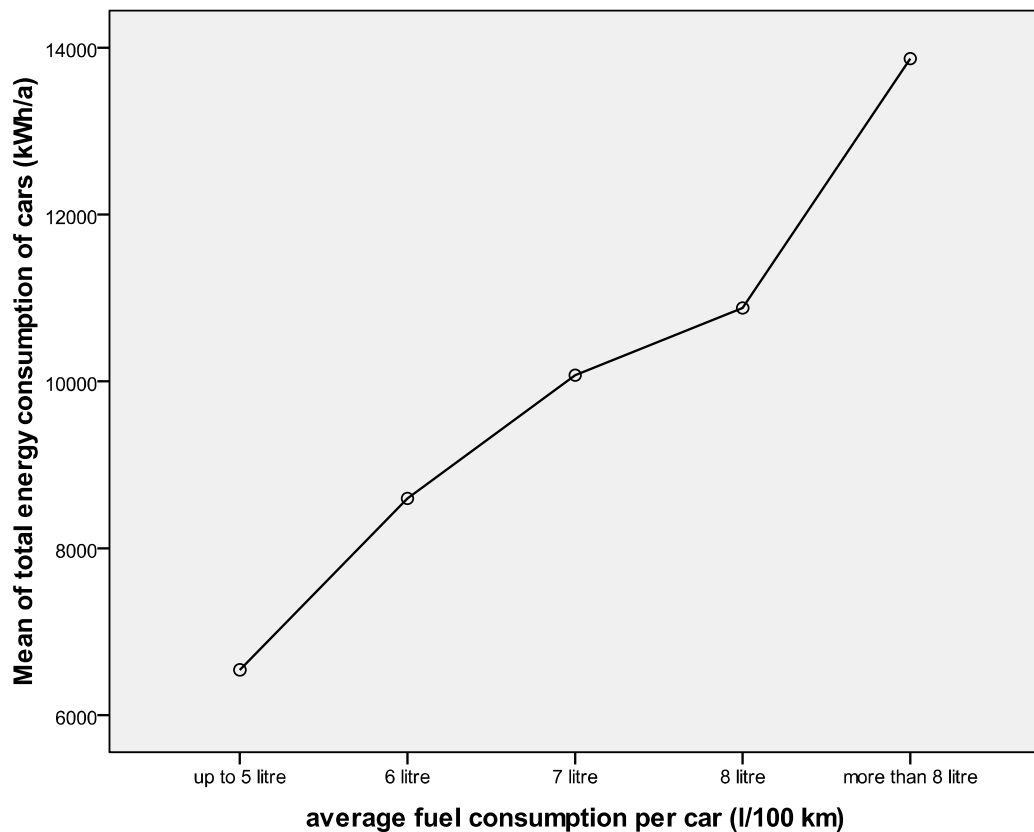


Figure 22: Mean of total energy consumption of cars apportioned from fuel efficiency of cars

Passenger car energy consumption and household size

A one-way ANOVA has been applied with passenger car energy consumption as dependent variable and household size as independent variable. Post hoc tests have been used to indicate the differences in energy consumption between the different levels of household size.

There was a significant effect of household size on passenger car energy consumption ($F(4, 205) = 16.72, p < 0.001, \omega = 0.28$), indicating that

as household size increased, energy consumption increased proportionately (Fig.23). Planned contrasts revealed that single person households compared with two-person households are on average using 1329 kWh/a less energy ($t(349.74) = 2.92$, $p < 0.01$, $r = 0.15$), whereas there was no significant difference between three-, four- and five-and-more person households. The largest difference in energy consumption in terms of household size was between two- and three person household (1872 kWh/a, $p < 0.01$).

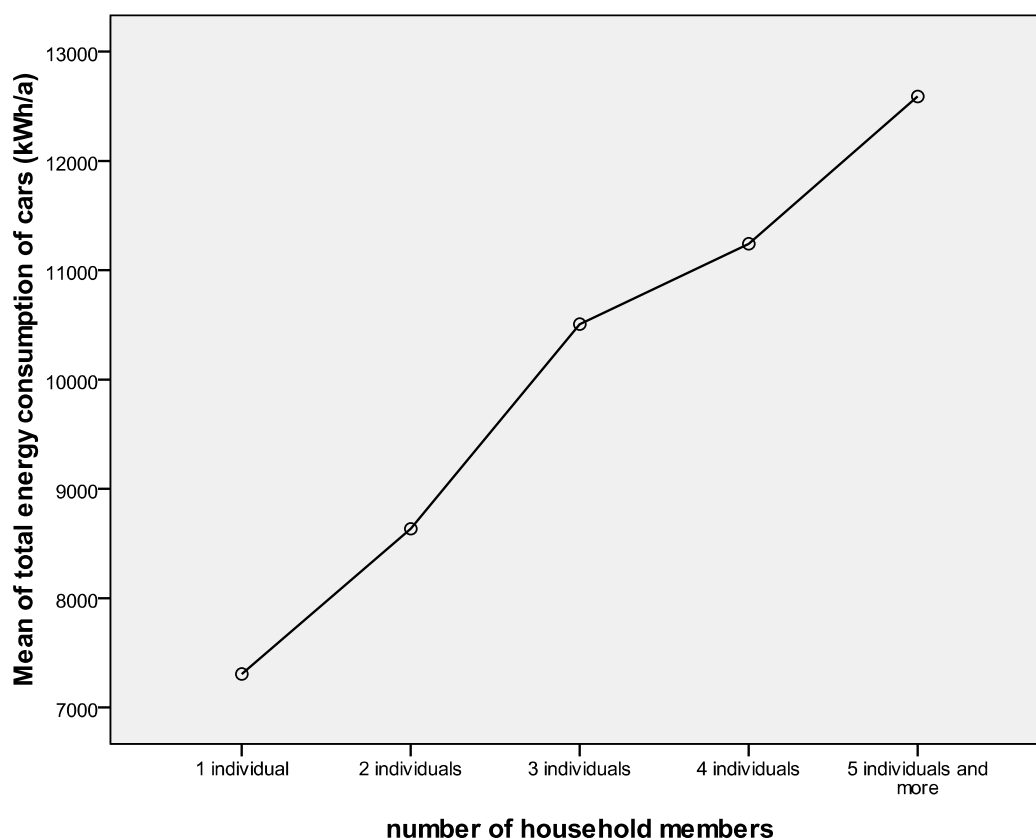


Figure 23: Mean of total energy consumption of cars apportioned from number of household members

Passenger car energy consumption and number of children

An analysis has been conducted in order to assess the effect of number of children on passenger car energy consumption using one-way ANOVA. Specific hypothesis have been tested to evaluate the differences of energy consumption across the various levels of the factor variable.

The ANOVA test statistic reported a significant effect of number of children on passenger car energy consumption ($F(2, 750) = 6.58, p < 0.01, \omega = 0.12$). A planned contrast revealed that households having no children ($t(750) = 3.58, p < 0.001, r = 0.13$) are using significantly less energy compared to households having at least one child (Fig. 24).

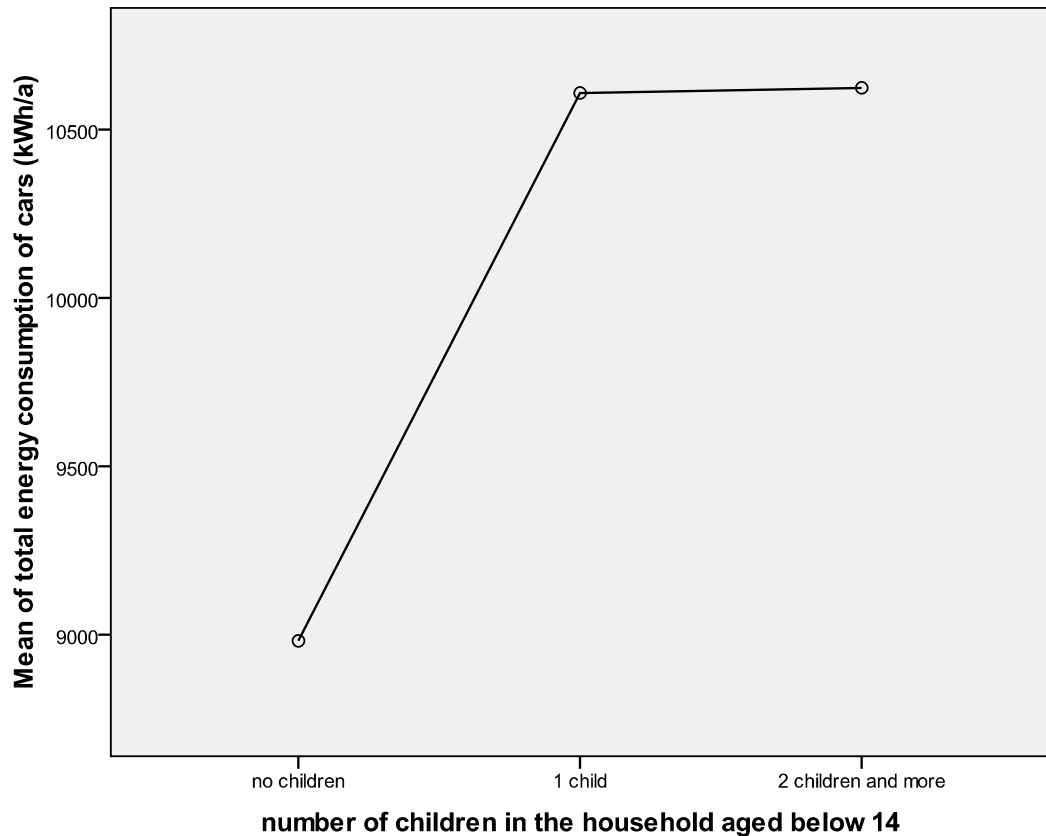


Figure 24: Mean of total energy consumption of cars apportioned from number of children in the household aged below 14

Passenger car energy consumption and age-group

The ANOVA design has been applied to test the effect of age on passenger car energy consumption as dependent variable. Planned contrasts have been set up to test whether there is a significant difference across specific age-groups.

The ANOVA test statistic showed a significant effect of age-group on passenger car energy consumption ($F(11, 207.04) = 5.99, p < 0.001, \omega =$

0.22). A planned contrast indicated that the age-group of 19 to 59, apparently non retired persons, is using significantly more energy ($t(144.69) = 2.94, p < 0.01, r = 0.24$) than the age group from 59 to 69 which is comprising mainly retired persons. Figure 25 depicts a rising trend of energy consumption beginning with the age-group of 25 to 29 years culminating in a peak in the years of 45 to 49 years and downward trend until the group of 70 years and older with a peak in the group of 60 to 64 years

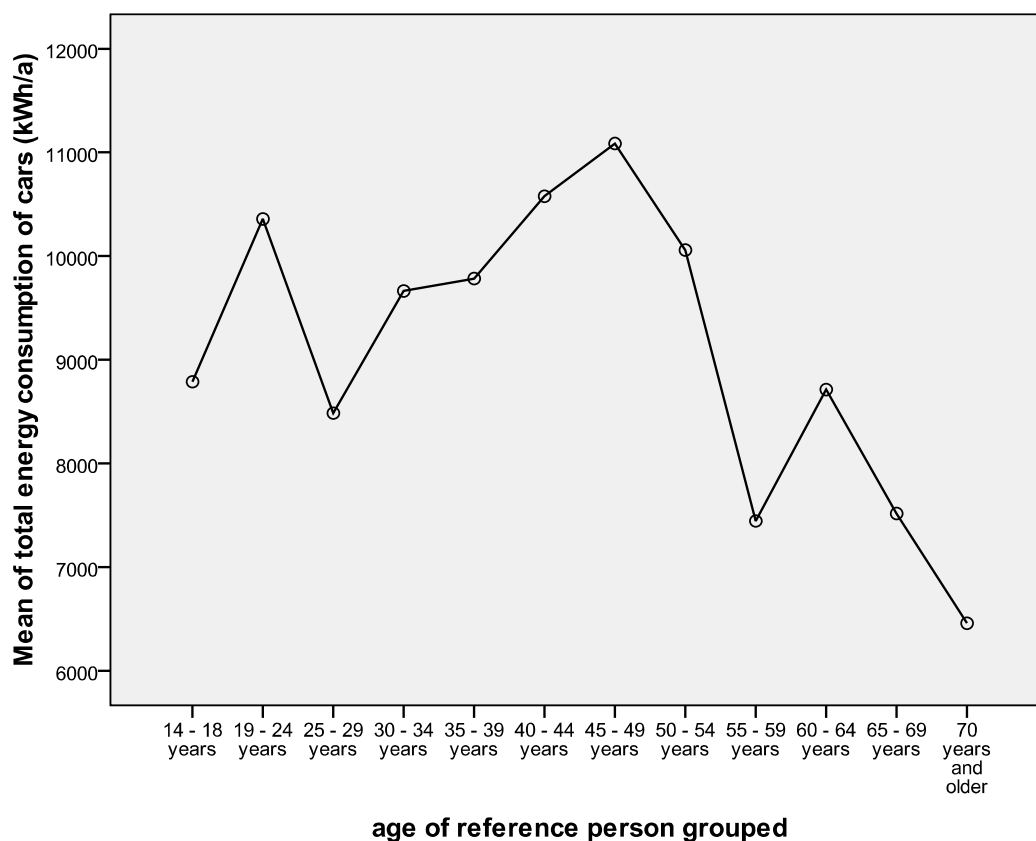


Figure 25: Mean of total energy consumption of cars apportioned from age-group

Passenger car energy consumption and degree of urbanity

One-way ANOVA design has been applied with passenger car energy consumption as dependent variable and degree of urbanity as independent variable.

There was a non-significant effect of degree of urbanity on passenger car energy consumption ($F(5, 747) = 0.94, p = 0.453$). Therefore degree of

urbanity is not significantly influencing energy consumption. The means of the corresponding factors levels are plotted in figure 26.

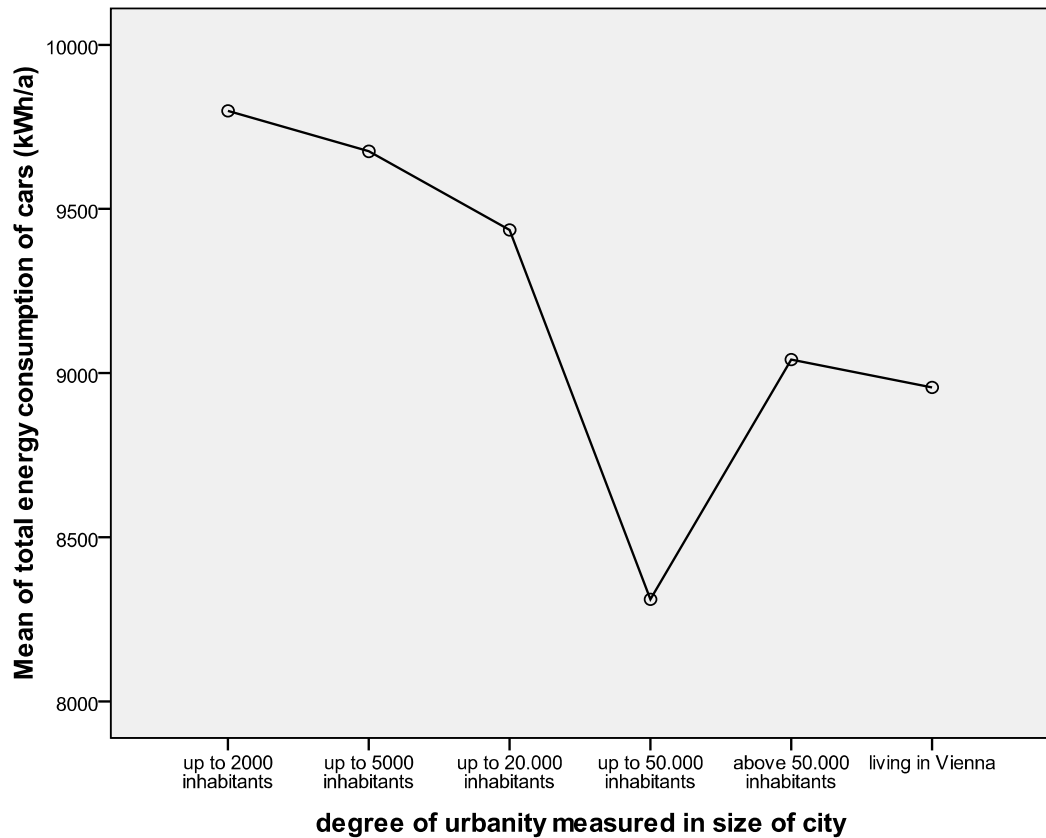


Figure 26: Mean of total energy consumption of cars apportioned from degree of urbanity measured in size of city

Passenger car energy consumption and education

An analysis has been conducted in order to assess the effect of education on passenger car energy consumption using one-way ANOVA. Specific hypothesis have been tested to evaluate the differences of energy consumption across the various levels of the factor variable.

The ANOVA test statistic reported a significant effect of education on passenger car energy consumption ($F(4, 193.87) = 3.46, p < 0.01, \omega = 0.12$). Planned contrasts revealed that the households with a reference person having compulsory school education compared to all other levels of education ($t(138.75) = 3.22, p < 0.01, r = 0.26$) are using significantly less

energy (Fig. 27). Furthermore, a reference person with the educational level of university degree is using significantly more energy when compared to the other levels ($t(59.01) = -2.02, p < 0.05, r = 0.25$).

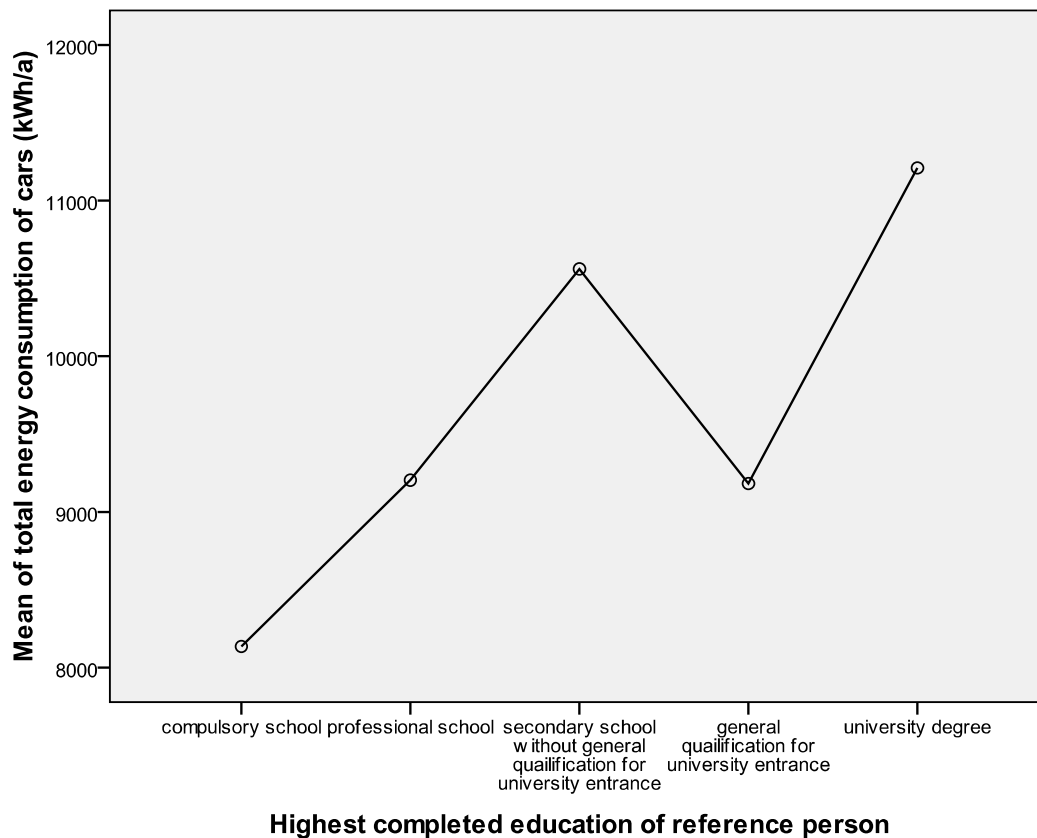


Figure 27: Mean of total energy consumption of cars apportioned from highest completed education of reference person

Passenger car energy consumption and household income

One-way ANOVA design has been performed to indicate the effect of household income on passenger car energy consumption as dependent variable. The application of post hoc tests assessed the differences in energy consumption between the different levels of household income.

There was a significant effect of household income on passenger car energy consumption ($F(4, 97.67) = 27.53, p < 0.001, \omega = 0.39$), indicating that as household income increased, energy consumption increased proportionately in an almost linear way (Fig. 28). Post hoc tests revealed that households with an income up to € 1.049, between € 1.050 and € 2.099 and

between € 2.100 and € 2.999 do not differ among each other ($p > 0.05$). However, income levels of € 3.000 to € 3.999 and of € 4.000 and more are using significantly higher amounts of energy in passenger car transport when compared to the previous levels ($p < 0.05$) and among themselves with a mean difference of about 3390 kWh per year ($p < 0.01$).

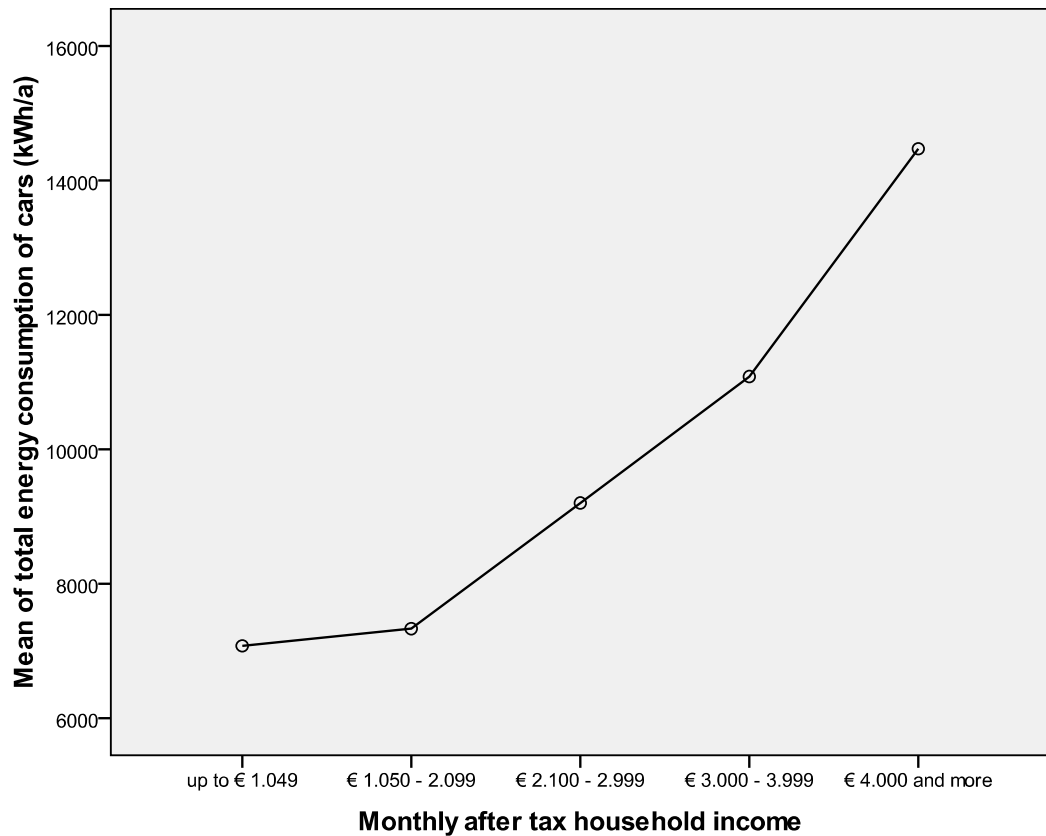


Figure 28: Mean of total energy consumption of cars apportioned from monthly after tax household income

3.3. Factors related to public transport consumption patterns

This paragraph is establishing the relationship between and the effect of socio-economic variables on public transport energy consumption patterns.

Multi-factorial ANOVA evaluated the interaction between socio-economic variables and extracted the exclusive effect of each factor on public transport energy consumption and the interaction between them.

One-way ANOVA designs have been performed in order to examine the differences of public transport energy consumption in the various levels of socio-economic variables by applying specific constellations of analysis (planned contrasts and post hoc tests).

Preliminary data analysis and preparation

As encountered in section 3.2 the methodology for detection and removal of outliers of public transport energy consumption has been applied in order to come up with a less biased sample.

In the next step K-S and Levene's tests have been conducted in order to test for normal distribution and homogeneity of variance of public transport energy consumption within the factor variables:

- household size
- number of children
- age
- degree of urbanity
- education
- household income

The K-S test statistics have been analysed in conjunction with histograms and Q-Q chart plots in order to get a more informed decision on the normal distribution of socio-economic variables. The plots indicated that there were no severe deviations from normality of socio-economic variables.

By means of transformation using natural logarithm the variances have been homogeneous for household size, degree of urbanity, education and household income. However, for the variable number of children transformation was not successful and hence has been excluded from multi-factorial ANOVA. Additionally, one-way ANOVA designs which are more robust in terms of violations of homogeneity of variance have been chosen in order to assess the extent of variation in public transport energy consumption among socio-economic variables.

Interaction among socio-economic factors and its associated impact on public transport energy consumption

A four-way ANOVA of public transport energy consumption has been performed with the variables household size, degree of urbanity, education and household income.

There was a significant main effect of household size ($F(4, 435) = 3.98, p < 0.01, \eta^2 = 0.04$), degree of urbanity ($F(5, 435) = 10.11, p < 0.001, \eta^2 = 0.1$) and household income ($F(4, 435) = 2.93, p < 0.05, \eta^2 = 0.03$) on public transport energy consumption. The extent of the impact of the socio-economic variables on public transport energy consumption is generally low. However, the variable exerting the most influence on energy consumption is degree of urbanity. For the variable education the ANOVA test statistics reported a non-significant effect ($F(4, 435) = 1.49, p = 0.204$) on energy consumption. This result contradicts to the test statistic of the one-way ANOVA (as explained later). However, since the variance in a one-way ANOVA design is not divisional down into parts of variance explained solely by the factor variables included, the results of the one-way ANOVA should be disregarded when compared with the multi-factorial design. No interaction effects have been observed among the socio-economic variables, thus they are not contributing to the differentiation in public transport energy consumption.

The results of the analysis showed that the variables household size, degree of urbanity and household income are influencing and differentiating the amounts of energy consumed by households in public transport. The more detailed impacts of these socio-economic variables on public transport energy consumption will be explained in the later section of univariate ANOVAs.

When examining the post hoc procedures the analysis revealed that the differences in factor levels across all socio-economic variables except for highest completed education have been the same as for the separate one-way ANOVA designs. For this reason the differences in absolute terms are even valid without considering interaction effects.

Explaining public transport energy consumption by socio-economic factors

This section addresses public transport energy consumption by analysing and contrasting the differences between the various levels of socio-economic variables. Post hoc tests and planned contrasts and procedures have been chosen in order to test specific hypotheses, whereas contrasts have been preferred due to greater statistical power. To this end separate one-way ANOVA designs have been conducted on each of the socio-economic variables.

Public transport energy consumption and household size

An analysis has been performed in order to measure the effect household size on public transport energy consumption using one-way ANOVA. Specific hypothesis have been tested to evaluate the differences of energy consumption across the various levels of the factor variable.

A significant effect on passenger car energy consumption ($F(4, 153.23) = 16.72, p < 0.001, \omega = 0.33$) has been observed, indicating that as the household size increased, energy consumption increased proportionately from one to four household members (Fig. 29). Planned contrasts showed that single person households are on average using less energy than two-person households ($t(430.89) = 4.52, p < 0.001, r = 0.21$). Controversly, as shown in figure 28 households with five individuals and more are using significantly less energy for public transport than four person households. However, this result is unreliable since outliers on the upper limit have been mainly removed from the last factor level of number of household members and hence reducing the sample size of the corresponding factor level to an invalid size which is not applicable for statistical analysis.

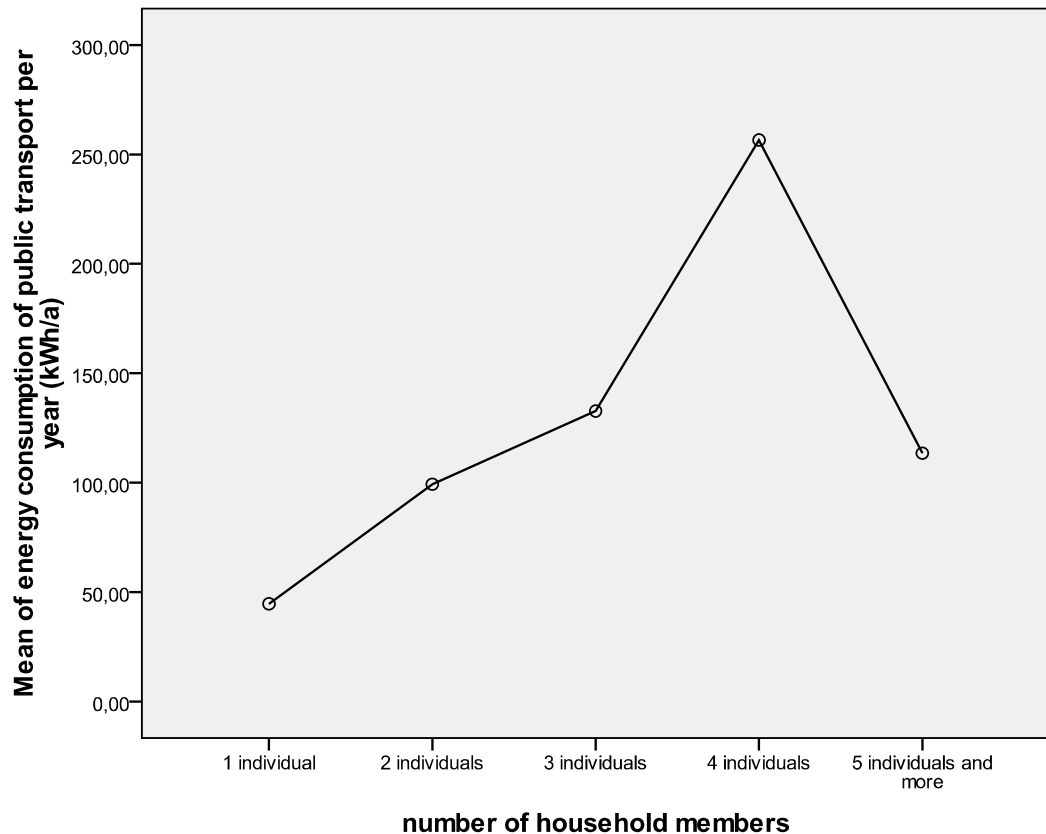


Figure 29: Mean of energy consumption of public transport apportioned from number of household members

Public transport energy consumption and number of children

One-way ANOVA design has been applied with public transport energy consumption as dependent variable and number of children as independent variable.

There was a significant effect of number of children on public transport energy consumption ($F(2, 713) = 31.42, p < 0.001, \omega = 0.29$). Furthermore, a planned contrast showed that households having no children ($t(150.98) = 5.96, p < 0.001, r = 0.44$) are using significantly less energy than households having one children (Fig. 30).

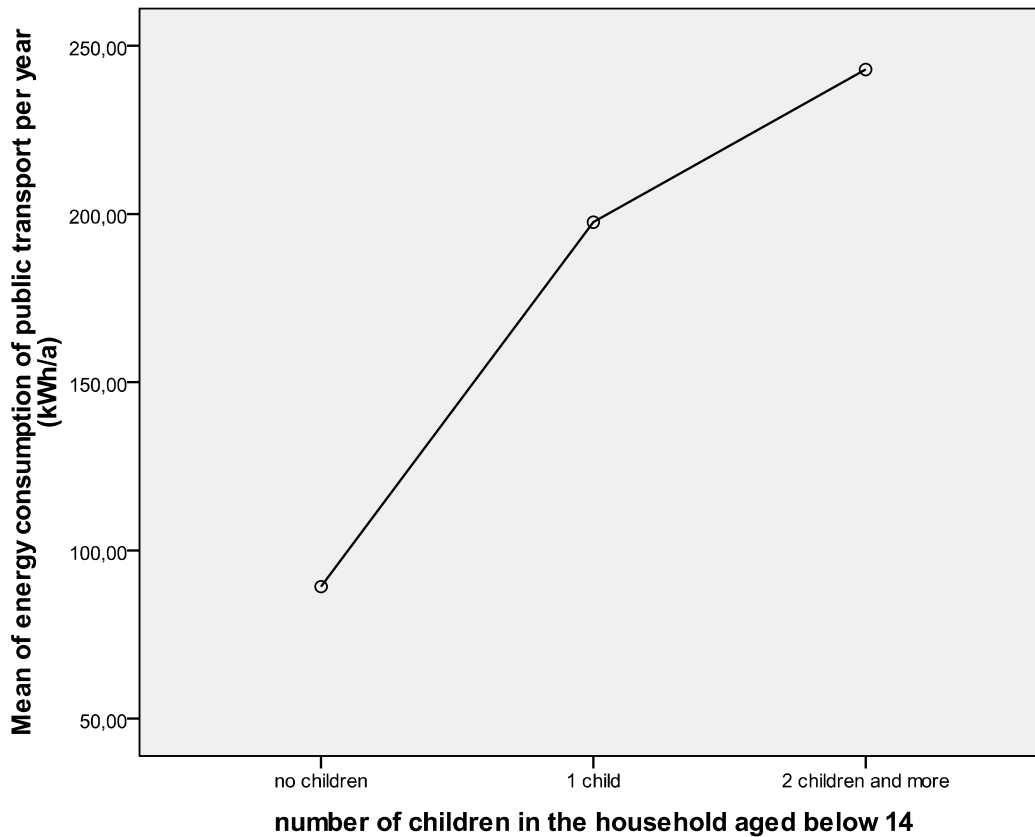


Figure 30: Mean of energy consumption of public transport apportioned from number of children in the household aged below 14

Public transport energy consumption and age-group

The ANOVA design has been applied to test the effect of age on public transport energy consumption as dependent variable. Planned contrasts have been set up to test whether there is a significant difference across specific age-groups.

The analysis revealed a significant effect of age-group on public transport energy consumption ($F(11, 207.04) = 5.99, p < 0.001, \omega = 0.22$). A planned contrast indicated that the age-group of 19 to 59, apparently non retired persons, is using significantly more energy ($t(169.72) = 4.73, p < 0.001, r = 0.34$) than the age group from 59 to 69 which is comprising mainly retired persons. As shown in figure 31 a declining trend of energy consumption beginning with the age-group of 35 to 39 has been observed. Two peaks of public transport energy consumption are located in the years of 14 to 18 and 35 to 39.

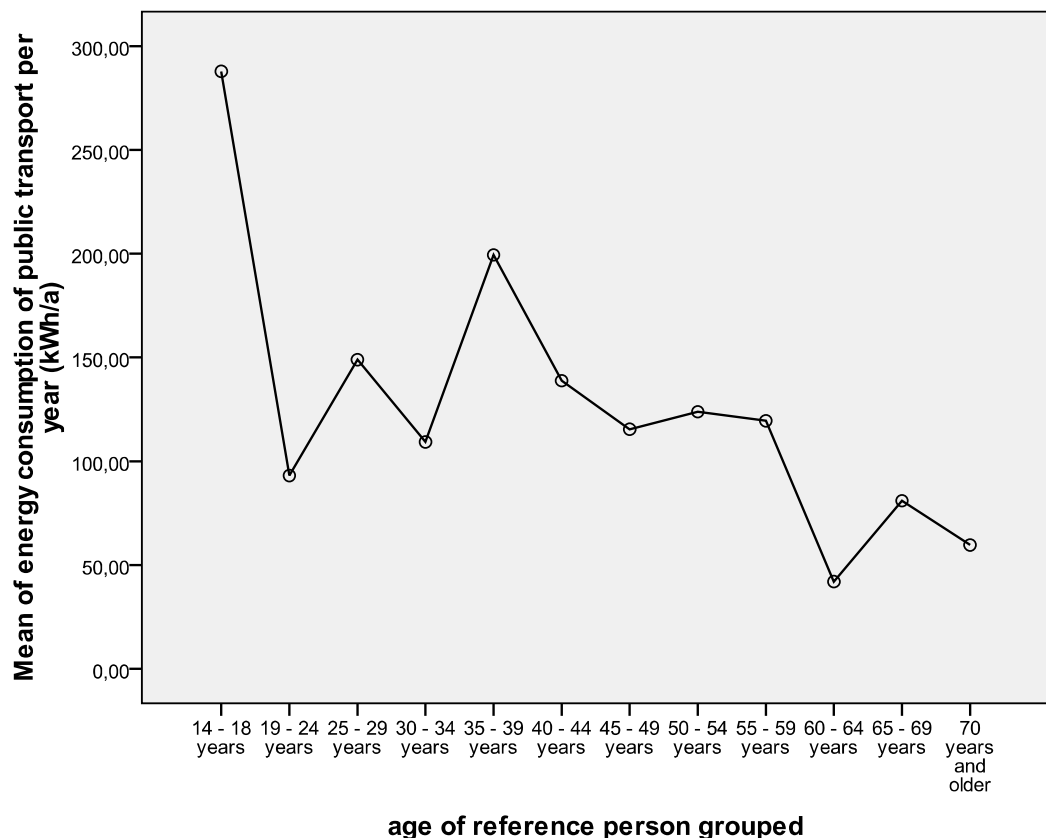


Figure 31: Mean of energy consumption of public transport apportioned from age-group

Public transport energy consumption and degree of urbanity

A one-way ANOVA has been applied with public transport energy consumption as dependent variable and degree of urbanity as independent variable. Post hoc tests have been used to indicate the differences in energy consumption between the different levels of degree of urbanity.

There was a significant effect of degree of urbanity on public transport energy consumption ($F(5, 226.1) = 9.16, p < 0.001, \omega = 0.24$). When comparing cities of not more than 2000 inhabitants with city with the other factor levels ($t(270.36) = 3.77, p < 0.001, r = 0.22$) planned contrasts showed that the later levels are using significantly more energy in public transport. The factor levels with the least amount of public transport energy consumption are cities up to 2000 and cities up 20.000 inhabitants (Fig. 32),

whereas post hoc tests indicated that there is no significant difference between these two levels ($p = 0.958$).

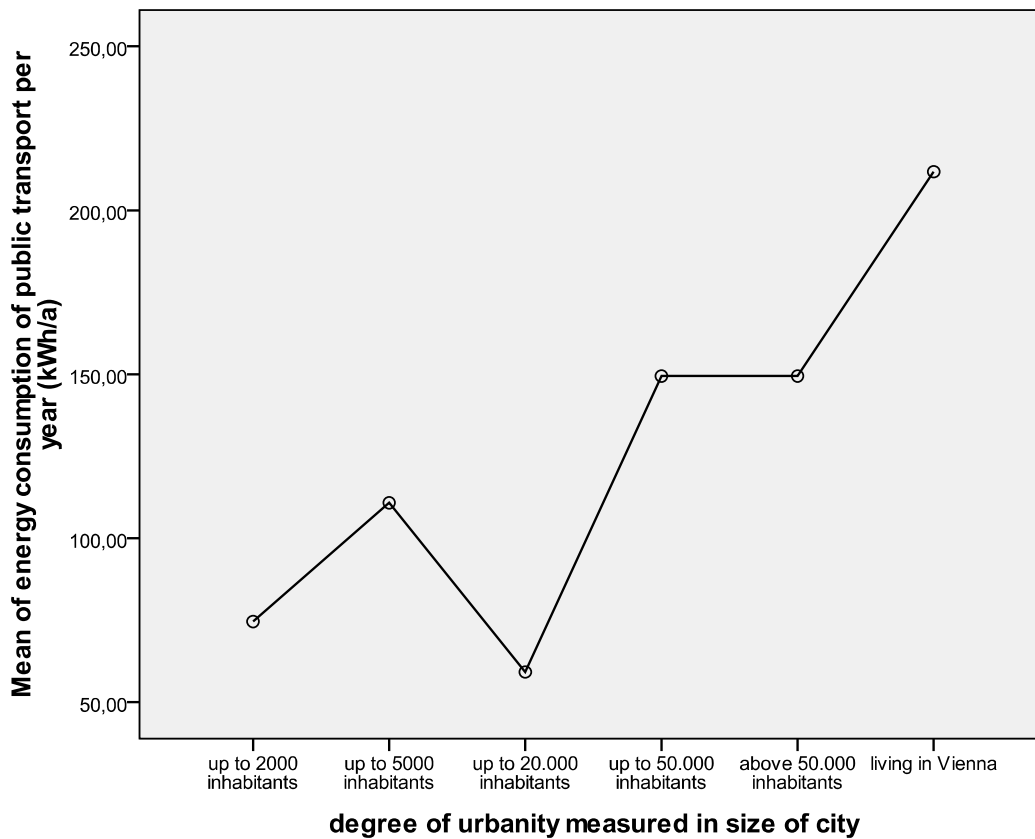


Figure 32: Mean of energy consumption of public transport apportioned from degree of urbanity measured in size of city

Public transport energy consumption and education

One-way ANOVA design has been performed to indicate the effect of highest completed education of reference person in the household on public transport energy consumption as dependent variable. The application of planned contrasts assessed the differences in energy consumption between the different levels of education.

The test statistic reported a significant effect of education on public transport energy consumption ($F(4, 180.05) = 3.46, p < 0.05, \omega = 0.15$). Planned contrasts revealed that the households with a reference person having compulsory school education compared to all other levels of education ($t(119.62) = 2.6, p < 0.05, r = 0.23$) are using significantly less

energy (Fig. 33). A reference person with the educational level of university degree is using significantly higher amounts of energy when compared to the other levels ($t(52.11) = -3.19, p < 0.01, r = 0.4$). Furthermore, post hoc tests showed that there was no significant difference in energy consumption among the factor levels of compulsory school, professional school, secondary school without general qualification and secondary school with general qualification for university entrance.

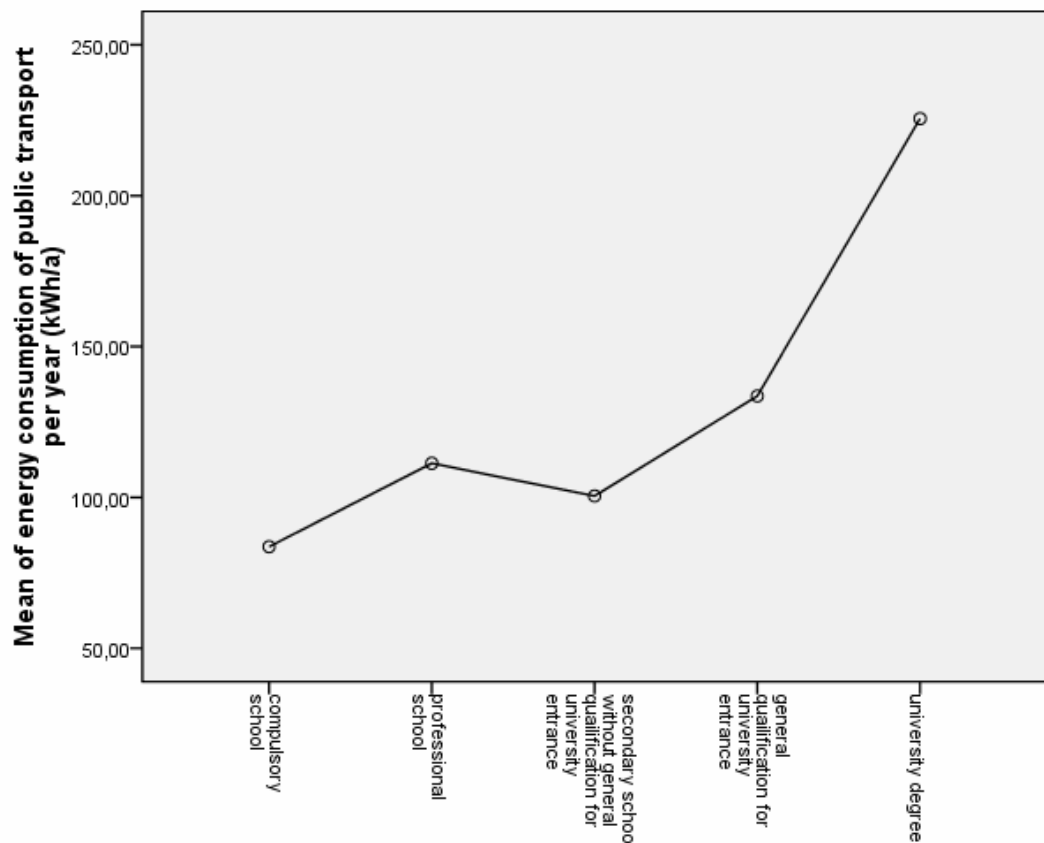


Figure 33: Mean of total energy consumption of public transport apportioned from highest completed education of reference person

Public transport energy consumption and household income

An analysis has been performed in order to assess the effect of monthly after tax household income on public transport energy consumption using one-way ANOVA. Specific hypotheses have been tested to evaluate the differences of energy consumption across the various levels of the factor variable.

A significant effect of household income on public transport energy consumption ($F(4, 97.66) = 13.26, p < 0.001, \omega = 0.27$) has been observed. Figure 34 depicts an upward trend of public transport energy consumption until the factor level of € 3.000 to € 3.999, whereas there is no significant difference between the two lowest levels ($p = 0.997$). Planned contrasts revealed that when comparing households with an income up to € 1.049 against all other factor levels together ($t(21.78) = 3.14, p < 0.01, r = 0.51$) households with an income up to € 1.049 are using significantly less energy. Households with income levels of € 3.000 to € 3.999 are using more energy than households earning € 4.000, although the difference is non-significant ($p = 0.972$).

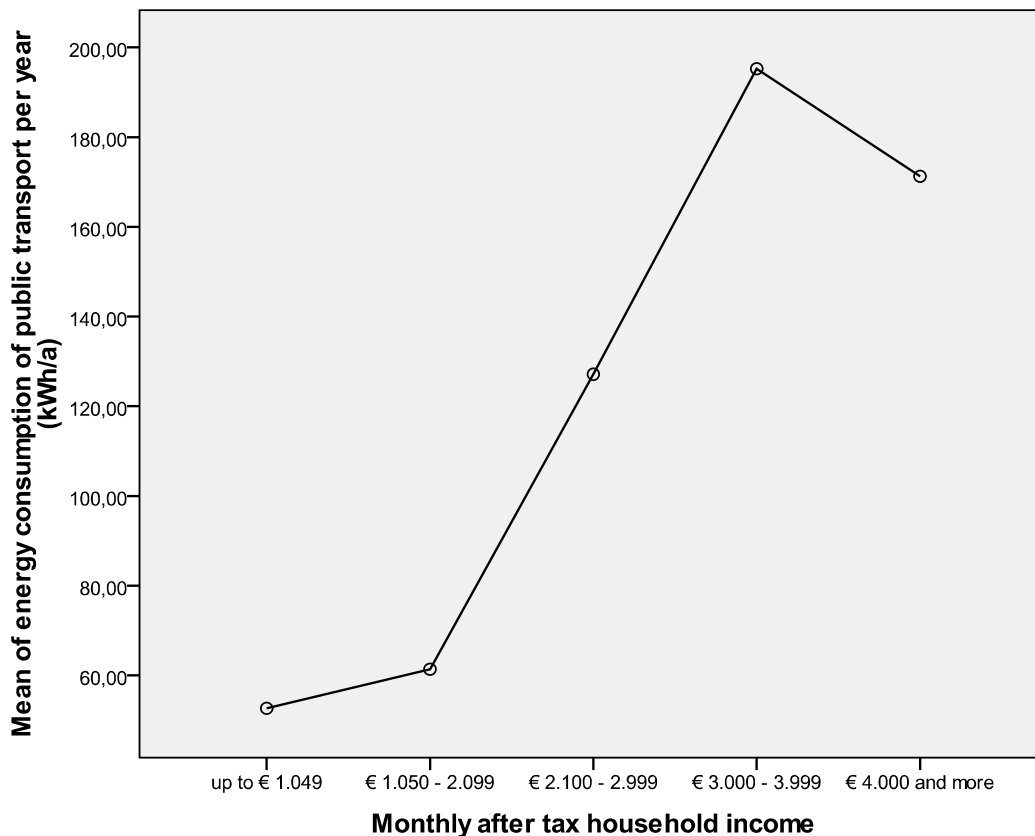


Figure 34: mean of total energy consumption of public transport apportioned from monthly after tax household income

3.4. Factors related to air travel energy consumption patterns

In this section of the study the effect of socio-economic variables on air travel energy consumption patterns has been addressed. To this end one-way ANOVA designs have been applied to display any differences of air travel energy consumption across socio-economic variables. Planned contrasts and post hoc were essential methods of analysis in order to test specific hypotheses. However, the application of a multi-factorial ANOVA design was not practicable, since assumption of homogeneity has not been accomplished.

Preliminary data analysis and preparation

The detection and removal of outliers was a first and essential step in order to come up with a more reliable sample.

K-S and Levene's tests were necessary in order to test for normal distribution and homogeneity of variance respectively within the factor variables:

- household size
- number of children
- age
- degree of urbanity
- education
- household income

An integrated analysis by means of K-S test statistics, histograms and Q-Q chart plots enabled a more informed decision on the normal distribution of socio-economic variables and hence no severe deviations from normality of socio-economic variables has been detected.

Nevertheless, efforts of transforming data by means of natural logarithm did not bring the anticipated result of homogeneity of variance. Therefore multi-factorial ANOVA has not been applied in the context of air travel energy consumption.

However, one-way ANOVA has been performed on each of the socio-economic variables separately because of its robustness in terms of

violations of homogeneity of variance and in order to assess the extent of variation in air travel energy consumption.

Explaining air travel energy consumption by socio-economic factors

The following steps deal with the analysis of differences of air travel energy consumption within socio-economic variables. The application of post hoc test and contrasts is specifying the differences by testing certain hypotheses.

Post hoc tests and planned contrasts and procedures have been chosen in order to test specific hypotheses, whereas contrasts have been preferred due to greater statistical power. Therefore one-way ANOVA designs have been conducted on each of the socio-economic variables separately.

Air travel energy consumption and household size

An analysis has been performed to assess the effect of monthly after tax household income on air travel energy consumption using one-way ANOVA. Specific hypotheses have been tested to evaluate the differences of energy consumption across the various levels of the factor variable.

A significant effect on air travel energy consumption ($F(4, 249.8) = 2.44, p < 0.05, \omega = 0.08$) has been assessed. Planned contrasts showed that single person households when compared with two-person households are using less energy ($t(607.63) = 2.78, p < 0.01, r = 0.11$). However, no apparent patterns of consumption from figure 35 could have been observed.

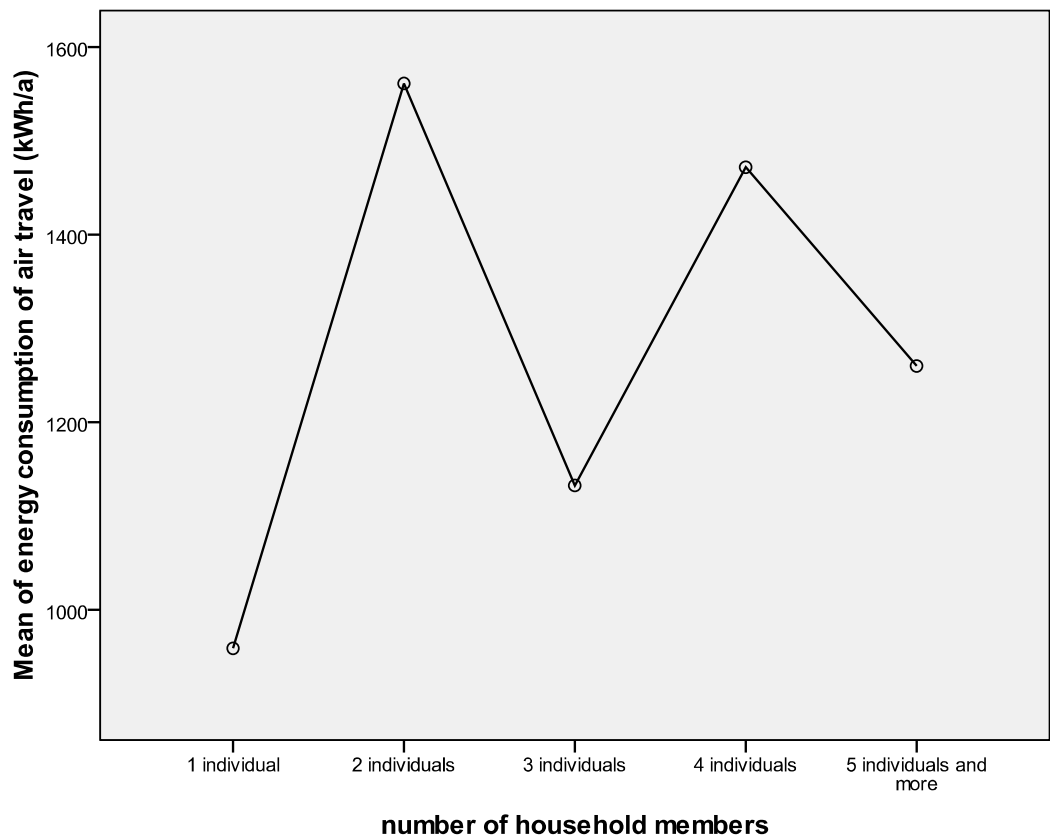


Figure 35: Mean of energy consumption of air travel apportioned from number of household members

Air travel energy consumption and number of children

The ANOVA design has been applied to test the effect on air travel energy consumption as dependent variable. Planned contrasts have been set up to test whether there is a significant difference across factor levels.

There was not a significant effect of number of children on air travel energy consumption ($F(2, 701) = 0.7, p = 0.496$). However, figure 36 depicts a difference in energy consumption between households with one and two children and more.

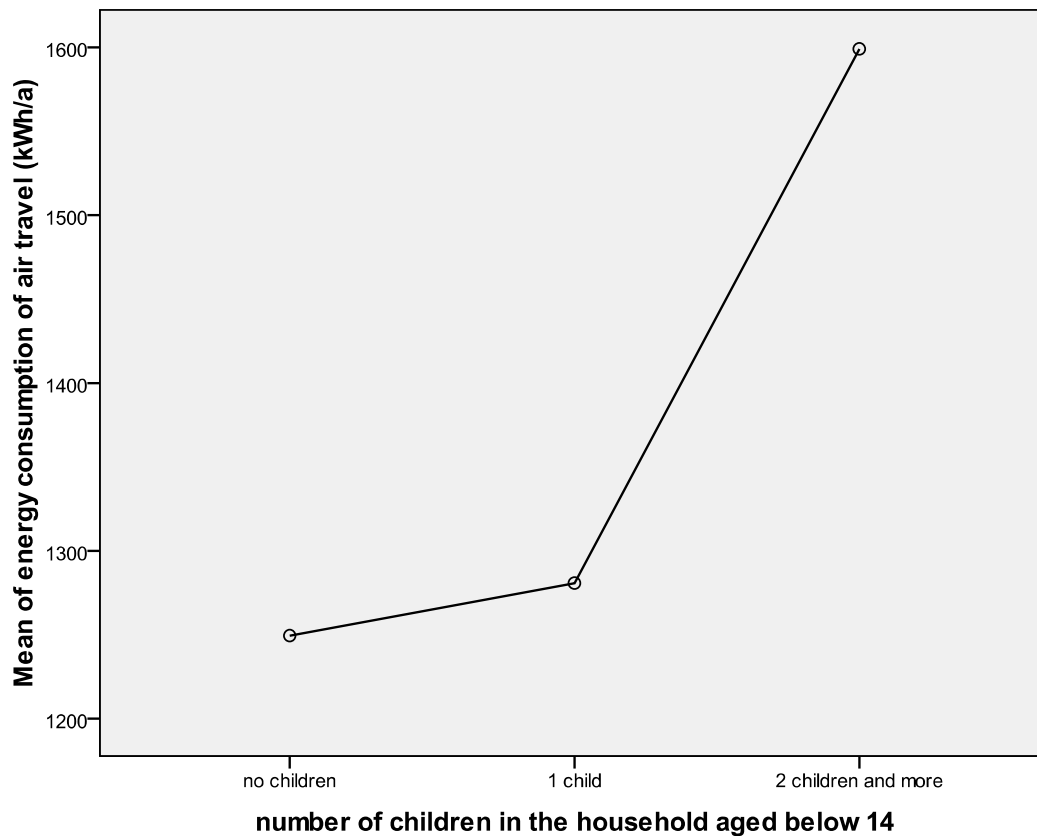


Figure 36: Mean of energy consumption of air travel apportioned from number of children in the household aged below 14

Air travel energy consumption and age-group

A one-way ANOVA has been applied with air travel energy consumption as dependent variable and age as independent variable. Post hoc tests have been used to indicate the differences in energy consumption between the different levels of age-group.

The analysis showed a significant effect of age on air travel energy consumption ($F(11, 297.48) = 8.71, p < 0.001, \omega = 0.16$). A planned contrast revealed that the households with a reference person of 19 to 59 years, apparently non retired persons, is using significantly more energy ($t(244.91) = 3.48, p < 0.01, r = 0.22$) than the age group from 59 to 69 which is mainly comprising retired persons. A declining trend of energy consumption beginning with the age-group of 14 to 18, as displayed in figure 37, has been observed. Peaks of air travel energy consumption are located in the years of 14 to 18, 30 to 34, 40 to 54 and 65 to 69.

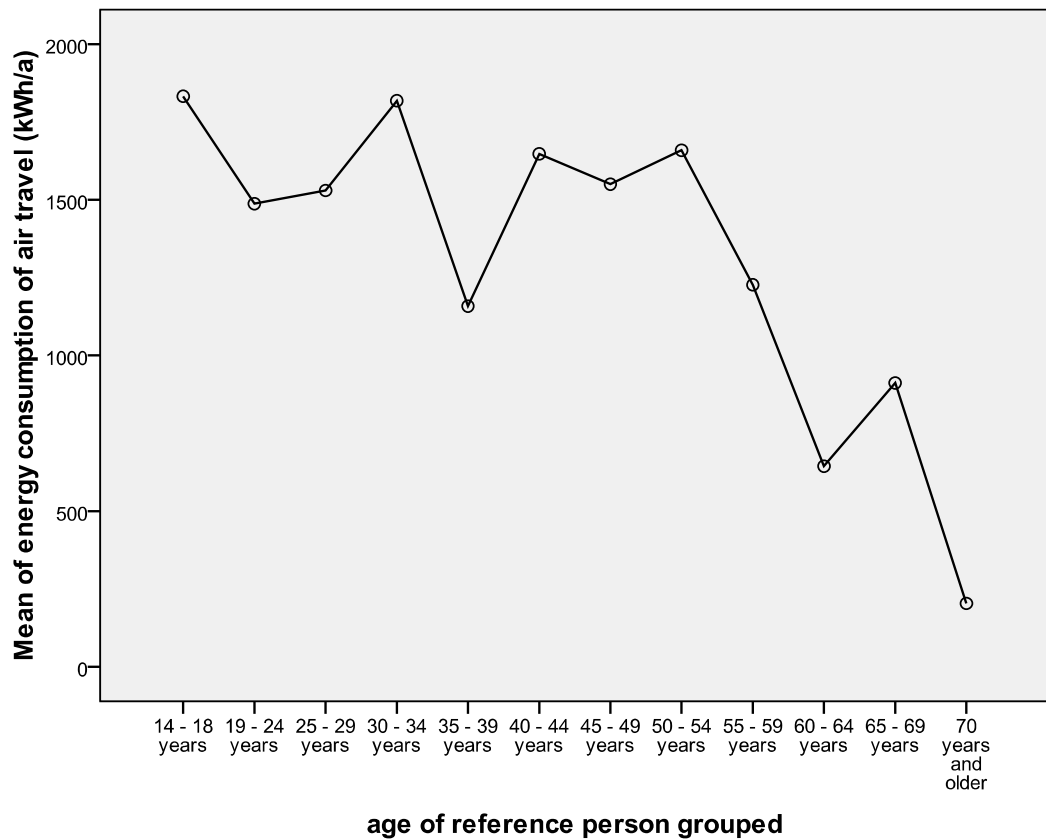


Figure 37: Mean of energy consumption of air travel apportioned from age-group

Air travel energy consumption and degree of urbanity

One-way ANOVA design has been performed to indicate the effect of degree of urbanity on air travel energy consumption as dependent variable. The application of planned contrasts assessed the differences in energy consumption between the different levels of urbanity.

There was a significant effect of degree of urbanity on air travel energy consumption ($F(5, 309.71) = 6.73, p < 0.001, \omega = 0.13$). The comparison of cities with not more than 2000 inhabitants and other factor levels by means of planned contrasts ($t(392.56) = 5.2, p < 0.001, r = 0.25$) indicated that the later levels are using significantly more energy regarding air travel. The factor levels with the least amount of air travel energy consumption are cities up to 2000 and cities up to 20,000 inhabitants (Fig. 38), whereas post hoc tests

indicated that there is no significant difference between these two levels ($p = 0.286$).

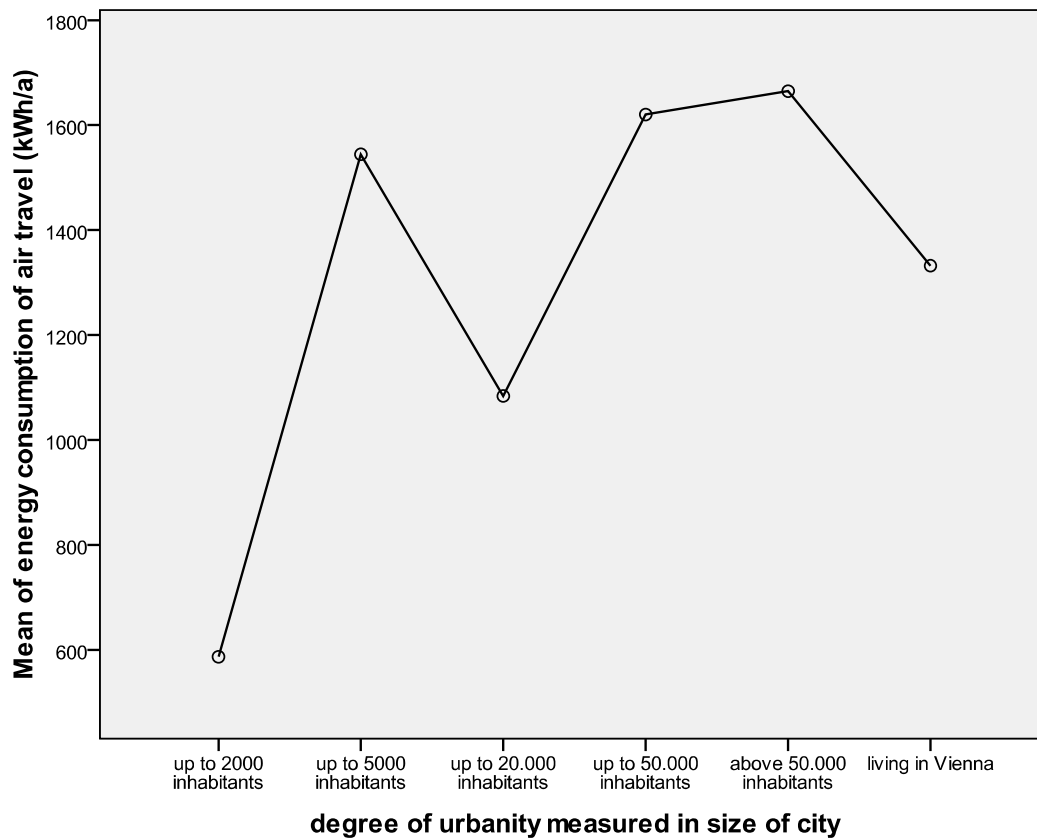


Figure 38: Mean of energy consumption of air travel apportioned from degree of urbanity measured in size of city

Air travel energy consumption and education

One-way ANOVA design has been applied with air travel energy consumption as dependent variable and education independent variable.

The test statistic reported a significant effect of education on air travel energy consumption ($F(4, 223.47) = 10.17, p < 0.001, \omega = 0.18$). A planned contrasts showed that the households with a reference person having compulsory school education compared to all other levels of education ($t(312.89) = 6.19, p < 0.001, r = 0.33$) are using significantly less energy (Fig. 39). On the other hand a reference person with the educational level of university degree is using significantly higher amounts of energy when compared to the other levels ($t(55.33) = -2.77, p < 0.01, r = 0.35$).

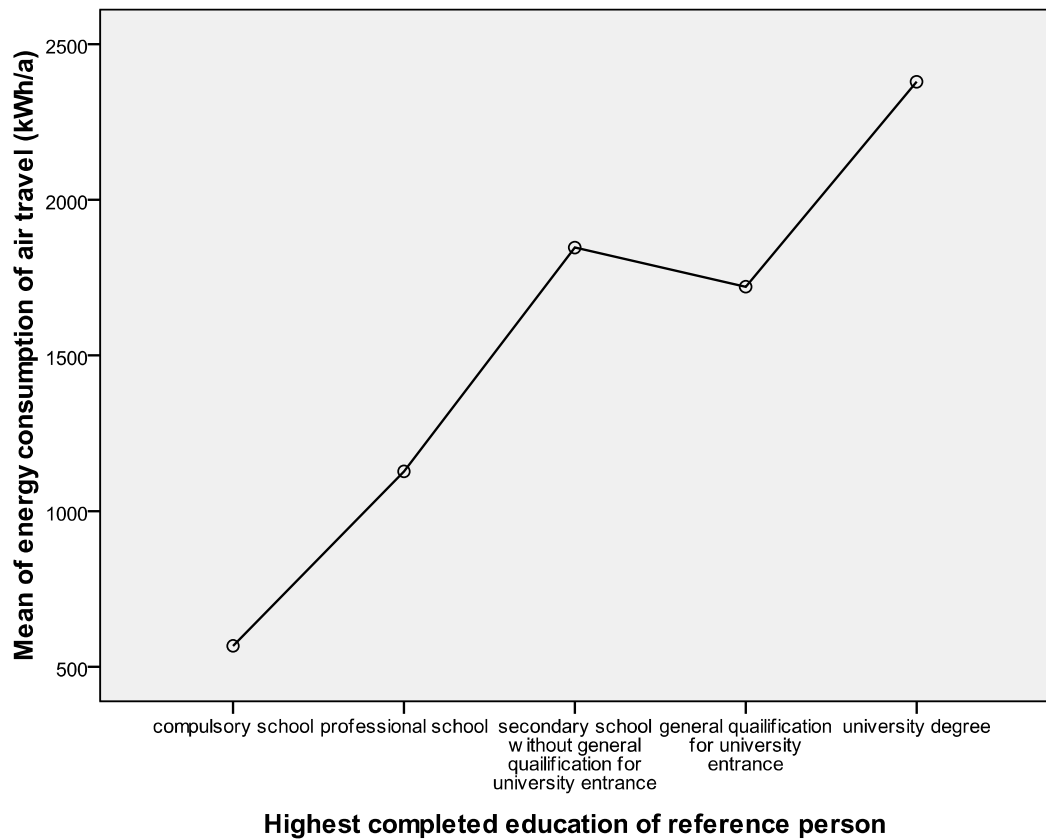


Figure 39: Mean of total energy consumption of air travel apportioned from highest completed education of reference person

Air travel energy consumption and household income

An analysis has been performed in order to measure the effect of Monthly after tax household income on air travel energy consumption using one-way ANOVA. Specific hypothesis have been tested to assess the differences of energy consumption across the various levels of the factor variable.

There was a significant effect of household income on air travel energy consumption ($F(4, 242.86) = 10.84, p < 0.001, \omega = 0.18$). A rising trend of air travel energy consumption until the factor level of € 3.000 to € 3.999 has been observed (Fig. 40), whereas as post hoc test revealed there was a non-significant difference between the two highest levels ($p = 1$). A planned contrast demonstrated that when comparing households with an income up to € 1.049 against all other factor levels together ($t(129.79) = 4.99, p <$

0.001, $r = 0.40$) households with an income up to € 1.049 are using significantly less energy.

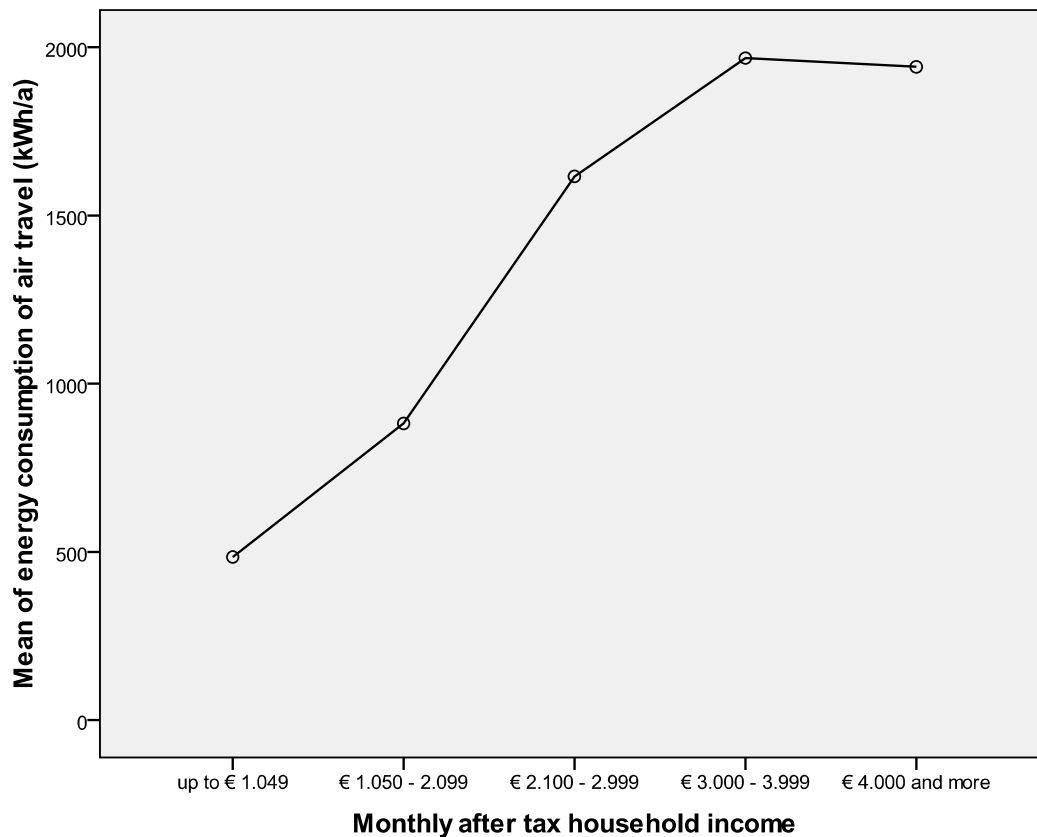


Figure 40: Mean of energy consumption of air travel apportioned from monthly after tax household income

3.5. An integrated view of private mobility energy consumption patterns

A MANOVA design has been applied with passenger car energy consumption and public transport energy consumption as dependent variables and household size, number of children, degree of urbanity, education, household income as independent variables. However, age has been excluded from further multivariate analysis due to inconsistent energy consumption patterns, indicating that mean energy consumption is considerably varying across age groups.

Using Pillai's trace, there was a significant effect of household size ($V = 0.06$, $F(8, 788)$, $p < 0.01$), degree of urbanity ($V = 0.09$, $F(10, 788)$, $p <$

0.001) and household income ($V = 0.06$, $F(8, 788)$, $p < 0.001$) on passenger car and public transport energy consumption.

In the following step discriminant function analysis (DFA) has been chosen for describing the nature of the relationship between the dependent variables passenger car, public transport and air travel energy consumption.

The socio-economic variables household income and degree of urbanity have been included in the DFA due to their statistical impact on the relationship between the dependent variables and their theoretical relationship to the dependent variables. However, the variable household size has been excluded from the analysis since the theoretical importance as discriminating factor is highly dependent upon its relation to other socio-economic variables. This variable has only been used in the analysis for illustrating the picture of rising energy consumption with increasing household size.

The DFA has been applied in conjunction with the socio-economic variable degree of urbanity measured in size of city, which revealed three discriminant functions. The first of these functions explained 84.1 percent of the variance ($R^2 = 0.08$), the second explained 12.7 percent of variance ($R^2 = 0.01$) and the third explained 3.2 percent of variance ($R^2 = 0.01$). As shown by the R^2 value the fit of the discriminant functions is substantially low and hence should be analysed in careful consideration. The three discriminant functions in combination significantly differentiated the factor levels of degree of urbanity ($\Lambda = 0.91$, $\chi^2(15) = 64.49$, $p < 0.001$). A correlation between outcome and discriminant functions showed that public transport energy consumption loaded high on function one ($r = 0.88$) and relatively low on the second ($r = -0.37$) and third function ($r = 0.3$); air travel energy consumption loaded more highly on the second function ($r = 0.91$) than on first function ($r = 0.42$); passenger car energy consumption loaded most highly on the third function ($r = 0.96$) and quite low on the first ($r = -0.23$) and second function ($r = 0.19$). As shown in the discriminant function plot (Fig. 41) function one is best for differentiating between high and low levels of urbanity, whereas for the second function this difference is considerably weak. However, due to the

low value of R^2 of the first, second and third function this difference is of low statistical significance.

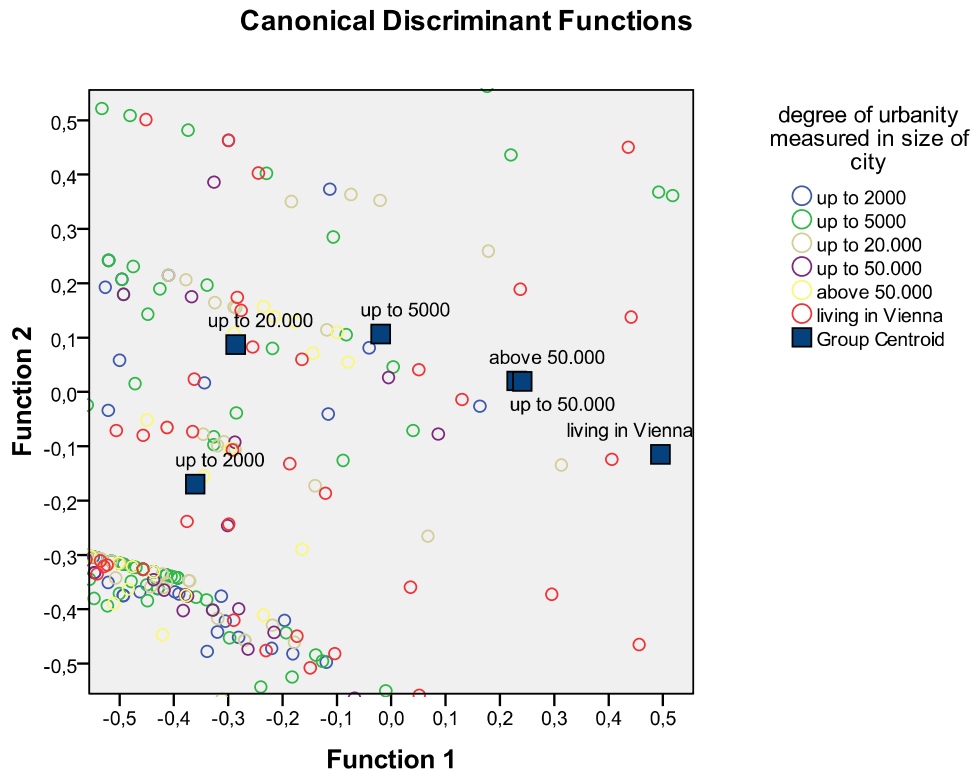


Figure 41: Canonical discriminant functions of degree of urbanity

Essentially as the DFA showed a classification of degree of urbanity in terms of mobility energy consumption has been achieved; a high degree of urbanity is characterized on the one hand with high public transport energy consumption and on the other hand relatively low passenger car energy consumption; a low degree of urbanity is related to a relatively high level of passenger car energy consumption and to a relatively low level of public transport energy consumption.

Regarding the results of the DFA for household income the analysis revealed three discriminant functions. The first explained 94.3 percent of variance ($R^2 = 0.21$), the second 5.4 percent ($R^2 = 0.02$), whereas the third only explained 0.2 percent ($R^2 = 0.001$). In combination the discriminant

functions significantly differentiated the factor levels of the grouping variable income ($\Lambda = 0.78$, $\chi^2(12) = 153.39$, $p < 0.001$). Correlations between outcome and discriminant functions revealed that passenger car energy consumption loaded more highly on function one ($r = 0.77$) than on function two ($r = -0.63$); public transport energy consumption loaded fairly high on function two ($r = 0.74$) and moderately on function one ($r = 0.53$); air travel energy consumption loaded high on the third function ($r = 0.89$). As displayed in figure 42 the first function discriminated best the lower levels of income from the higher ones. However, the low value of R^2 of the first, second and third function is indicating that the statistical significance is substantially.

As indicated by the analysis air travel energy consumption has been considerably disregarded. This was the case because of the fact that the discriminant functions which are highly correlated with air travel energy consumption are representing insignificantly low amount of variance explained.

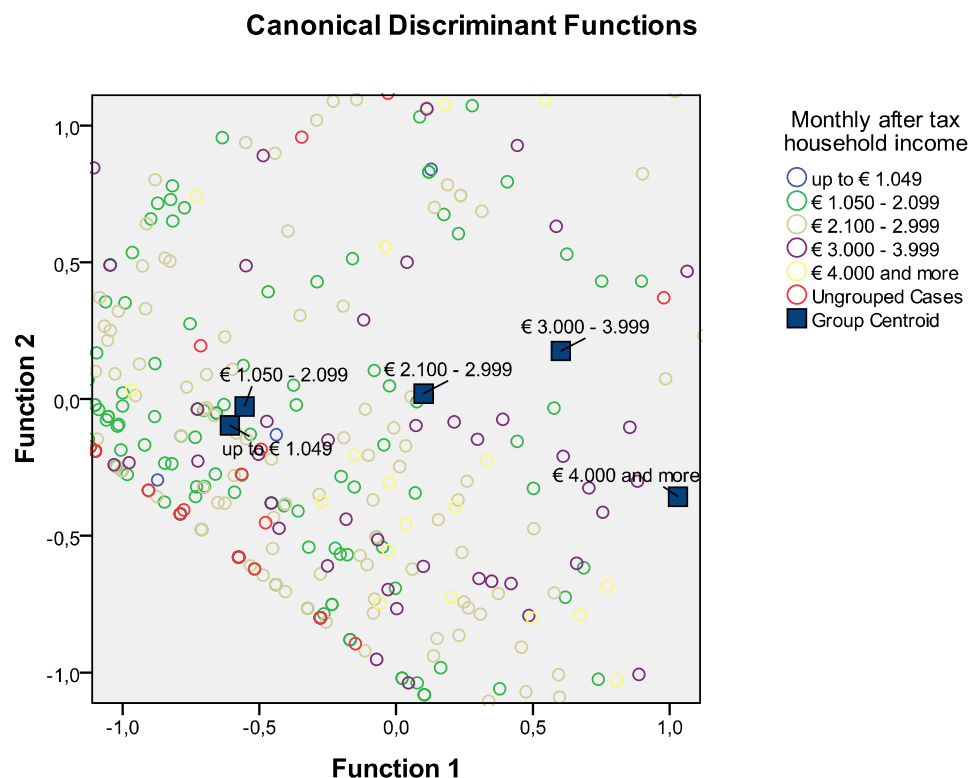


Figure 42: Canonical discriminant functions of household income

Function one has the best capability of separating groups. It indicates that higher amounts of passenger car energy consumption and public transport energy consumption are more related to higher income groups than to lower ones.

4. Discussion und Conclusions

The present study investigates the characterization of household energy consumption patterns in the mobility sector through socio-economic factors. To this end an holistic and integrated approach has been embraced in terms of household mobility patterns by examining passenger car, public transport and air travel. This required the comprehensive analysis of key drivers about their importance and influence on mobility energy consumption.

In regard to passenger car energy consumption, the results of the statistical analysis showed that monthly after tax household income and the household size were the only socio-economic factors differentiating energy consumption for private cars. In detail a higher level of household income is one of the main factors facilitating extensive passenger car energy consumption and furthermore, households with lower income levels are restricted in the use of passenger cars and consequently using less energy. The degree of urbanity was not significantly affecting the amount of energy consumption of passenger cars. However, a declining trend of passenger car energy consumption with rising degree of urbanity has been observed.

In the case of public transport, additionally, the degree of urbanity was contributing to describe the differences in energy consumption patterns. This indicates that only a high degree of urbanity might guarantee the necessary infrastructure to switch to more sustainable transport modes like public transport in terms of energy consumption. Therefore policies regarding urban planning and management, which are avoiding any forms of urban sprawl, might lead to a modal shift towards public transport and consequently lower amounts of mobility energy consumption.

Due to methodological reasons the socio-economic factors explaining air travel consumption patterns have been restricted to independent analysis and therefore are quite limited in terms of valid differentiation for an

integrated approach. However, the analysis showed that a declining trend of air travel energy consumption has been detected indicating that the younger generations are more active when it comes to air travel mobility. Besides, higher education is exerting a significant influence on the amount of energy consumed through air travel. The interest in other cultures and the pursuit of individual freedom through extensive travel might be one explanation for this trend. Still higher levels of household income are related to higher amounts of energy consumption in air travel despite the declining trend of short haul ticket prices and parallel rise in range. Otherwise factors not considered in this study like lifestyle preferences might influence households in their decisions about air travel.

As shown by the last paragraphs, we can assume that lower levels of income are more related to a low demand in passenger car energy consumption. In terms of mobility energy consumption patterns these households can be tentatively regarded as more sustainable than others, since relatively high levels of income are closely linked to higher disposable household income and consequently higher consumption. Thus certain policies which are fostering less energy intensive consumption patterns might counteract this relationship between rising disposable household income and increasing consumption. Certain Socio-economic groups have been identified, which are using significantly more energy than others, whereas only passenger car mobility and air travel have been considered, since they are on average accounting for 99 percent of total household mobility energy consumption. They are households with

- at least one child (also supported by Schipper et al., 1989; Moll et al., 2005)
- a high degree of urbanity (also supported by Schipper et al., 1989; Lenzen et al., 2004, Moll et al. 2005)
- higher levels of education and income (also supported by Schipper et al., 1989; Biesiot et al., 1999; Lenzen et al., 2004; Schlomann et al., 2004; Moll et al., 2005; Abrahamse & Steg, 2009);
- situated in the age-group of 19 to 59 (also supported by Schipper et al. 1989; VCÖ, 1999; Moll et al., 2005).

Households within the age-group of 19 and 59, although comprising a rather heterogeneous cluster, can be considered as more active and therefore related to higher energy demands in mobility. As already pointed out in the sector of air travel, higher levels of education might be related to a higher interest in other cultures and the pursuit of individual freedom through extensive mobility in general.

By embracing a more integrated view of mobility energy consumption, the results of the discriminant function analysis showed that degree of urbanity was affecting passenger car energy consumption. This reflects the non-significant trend of the ANOVA results. However, this result has to be examined with careful consideration due to the fact that ANOVA procedure has more statistical power in detecting true differences. To seriously deliberate these thoughts, the fact that households characterised by a high degree of urbanity use less energy in terms of passenger car mobility and more energy for public transport was of substantially low importance when considering the magnitude of this effect. From a statistical point of view we can say that there was a low but non significant effect of urbanity on passenger car energy consumption, whereas in terms of the amount of energy consumption this effect might be still important for a political context. This statistically non existent influence of urbanity on passenger car energy consumption is contradicting the results by Perrels (2008) in a Finnish context. However, the fact that households located in larger cities, offering a highly condensed infrastructure for recreation, shopping and commuting and a more developed infrastructure for public transport, which facilitates a modal shift from passenger car to public transport, contrasts the result of the present study. This might indicate that households in larger cities are taking advantage of the more developed infrastructure for public transport while keeping their relatively high energy consumption patterns for private cars. Therefore households characterised by a high degree of urbanity generally can be described as more active in terms of mobility.

Regarding the methodology of this study, more sophisticated statistical designs have been applied which are rarely encountered in this field of research and are therefore providing a high-resolution picture of mobility in terms of energy consumption and its underlying dimensions. In summary

household size, income and urbanity are the most important aspects for explaining household mobility consumption patterns. However, to go one step further the study examined the nature and extent of the impact of these socio-economic drivers on energy consumption. Despite the fact that household size, urbanity and income have been identified as main drivers their impact was substantially low throughout the different modes of household mobility. The overall low effect of the socio-economic drivers investigated in this study suggests that other aspects like culture and lifestyle are important in differentiating mobility energy consumption. The influence of these other aspects should be considered as equally important and the magnitude of their impact should not be underestimated. However, information on the extent of the impact of socio-economic variables on household mobility energy consumption in literature could not be identified.

Another interesting aspect obtained in this study is the absence of any interaction effects among socio-economic factors, which might have a substantial impact on the amount of energy consumed in passenger car and public transport. The absence of interaction effects indicates that none of the factor levels in a socio-economic variable is influencing a factor level of another variable in a non-consistent way – in other words there is a consistent relationship between socio-economic variables facilitating a clearer picture of their association. Therefore, the impact of socio-economic factors can be investigated in separate and independent steps delivering an analysis and interpretation of results which is more explicit, targeted and consistent. This was especially true for the interaction between socio-economic factors and their contribution for differentiating passenger car mobility.

Energy consumption for mobility is only one part of the total scope of consumption in households. Nevertheless, household mobility is a mayor one in terms of energy consumption and with respect to sustainability. Energy use related to electricity consumption or heating purposes, which comprises a considerable amount in the household's total energy requirement, and even estimations of energy use through indirect consumption (goods and services), have not been taken into account. Incorporating other aspects of

household energy consumption might be a promising step to embrace a more integrated approach in general and especially to explore any rebound effects concerning household consumption patterns.

As it has already been pointed out by various authors (Duchin, 1996; Weber & Perrels, 2000; Bohunovsky & Grünberger, 2010) household energy consumption patterns in general and especially household mobility consumption patterns cannot be explained solely by socio-economic factors but instead should be expatiated on a more complexity related and holistic approach. A number of studies (Schipper et al., 1989; Carlsson-Kanyama & Lindén, 1999; VCÖ, 1999; Lenzen et al., 2004; Moll et al., 2005; Druckman & Jackson, 2008; Abrahamse & Steg, 2009) have followed an approach in a more atomistic manner by using lifestyle, cultural or socio-economic aspects for describing energy consumption patterns of households. In order to fully understand the underlying drivers and determinants of energy consumption patterns of households in the mobility sector or overall, future research has to embrace this topic in a more holistic way. Moreover, such an approach could be enriched by integrating framework aspects like available technology, transport policy and infrastructure in the analysis.

Although drivers of household consumption suggest a comprehensive web of influence, socio-economic factors might be of considerable importance. They could act as a guidance and system of classification for governmental, economical, and institutional actors in order to develop targeted and demand oriented policies and programmes aiming at effectively reducing mobility energy consumption or supporting more sustainable patterns of consumption.

Furthermore, the identification of particularly vulnerable groups might be a connotative step for the design of more equitable and targeting measures. Vulnerable groups are households which either already have relatively low levels of mobility energy consumption or will suffer from the impact of these measures (e.g. low income households) and additionally constrict their constrained opportunities regarding mobility. To this end these vulnerable groups have to be supported by counteracting measures (e.g. transfer payments), when it comes to the implementation of fiscal policies (e.g. energy taxes) facilitating the transition to more sustainable patterns of

transport. On the other hand the effective implementation of policies in terms of achieving energy reduction or switching to less energy intensive modes of transport is dependent on the identification of groups which have relative high energy consumption patterns (e.g. high income groups). Thus, the introduction of a progressive tax regime for motor fuels by offering transfer payments to vulnerable groups might be an essential first step towards more equitable and demand oriented transport policies. However, only an integrated approach of transport policies for reducing energy consumption in mobility and associated environmental impacts might be a promising step. Such an approach incorporates measures like infrastructure development of public transport, campaigns for raising environmental awareness and fiscal policies.

Nonetheless, in order to essentially venture the transition towards sustainable patterns of mobility energy consumption and moreover a sustainable transport system, not only the implementation of contingent and sound policy strategies is necessary but also a major change in people's lifestyles and attitudes towards consumption.

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6. Annex

6.1. Curriculum vitae

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6.2. English abstract

There is growing concern that the environmental impacts originating from transport have increased over the last decade. Therefore this study investigates mobility energy consumption patterns of Austrian households and its associated socio-economic drivers. To this end the aim is to establish the link between household mobility consumption patterns and socio-economic variables in order to come up with a more differentiated and detailed picture of mobility energy consumption. The empirical basis of the study is data on energy consumption patterns in kWh per year in the area of passenger car and public transport as well as air travel. Households are characterized by socio-economic variables like income, degree of urbanity, number of children etc. By means of analysis of variance and discriminant function analysis socio-economic factors have been differentiated. Results showed that the most important driving factors for household mobility energy consumption were household size, income and urbanity. The absence of any interaction effects among socio-economic factors facilitated separate and independent analysis leading to a more targeted and explicit interpretation of results. Furthermore, by breaking down the variables into factor levels the study identified household characteristics related to a high degree of mobility energy consumption. These were households with at least one child, a high degree of urbanity and higher levels of education and income and within the age-group of 19 to 59. However, the analysis revealed that the impact of socio-economic drivers was substantially low throughout the different modes of household mobility. This suggests that the determinants of mobility energy consumption are manifold and vary in their influence and hence a more holistic approach has to be elaborated.

Key words: household energy consumption, mobility consumption patterns, transport, socio-economic analysis

6.3. German abstract

Die negativen Einflüsse des Verkehrs auf Umwelt und Gesellschaft sind in den letzten Jahrzehnten stark gewachsen. Aufgrund dieser Tatsache beschäftigt sich die vorliegende Arbeit mit den sozio-ökonomischen

Einflussparametern auf den Energieverbrauch österreichischer Haushalte im Bereich Verkehr. Das Ziel dieser Studie ist daher den Energieverbrauch der Haushalte mit sozio-ökonomischen Parametern in Beziehung zu setzen. Was wiederum zu einem differenzierteren und aufschlussreichem Bild bezüglich des Energieverbrauchs für Verkehr führen würde. Die Studie basiert auf Daten über den Jahresenergieverbrauch von Haushalten in kWh in den Bereichen PKW, öffentlicher Verkehr und Flugverkehr. Die Haushalte wurden durch sozio-ökonomische Parameter wie Einkommen, Urbanität, Anzahl der Kinder etc. definiert. Die Analysen wurden anhand von Varianz- und Diskriminanzanalysen durchgeführt. Die Ergebnisse zeigten, dass Einkommen, Urbanität und Haushaltsgröße die wichtigsten Einflussparameter auf den Energieverbrauch für Verkehr darstellen. Das Fehlen jeglicher Interaktionseffekte innerhalb der sozio-ökonomischen Parameter ermöglichte eine individuelle Analyse dieser Einflussfaktoren, was wiederum zu genaueren und expliziten Aussagen über die Ergebnisse führte. Durch eine detailreichere Aufschlüsselung der Parameter konnten Charakteristika identifiziert werden, die auf einen hohen Energieverbrauch im Bereich des Individualverkehrs hindeuteten: Haushalte mit zumindest einem Kind, einem hohen Grad an Urbanität, Bildung und Einkommen sowie der Altersgruppe zwischen 19 und 59. Allerdings zeigte die Analyse, dass der Einfluss sozio-ökonomischer Parameter quer über die verschiedenen Bereiche des Verkehrs – PKW, öffentlicher Verkehr und Flugverkehr – im statistischen Sinne wesentlich gering ist. Dies führt zur Annahme, dass die Einflussfaktoren auf den Energieverbrauch der Haushalte im Bereich Verkehr vielfältig sind und deren Einfluss stark variiert. Daher sind in der Forschung ganzheitlichere Ansätze gefordert, um dieser Problemstellung Rechnung zu tragen.