Title:

Generating customized sets of transport energy-saving measures for private households

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Abstract

The paper presents a method for generating an individual set of transport energy-saving measures for private households and shows how this process can be automated. The process is embedded in a study on the energy-relevant behaviour of about 700 households in Stuttgart considering both, residential and transport energy use. The households take part in a comprehensive household survey at first, providing the foundation for a subsequent potential analysis and the selection of measures. For this the paper compiles a systematic list of the most important energy-saving measures. As the study is still ongoing the paper focuses on the methodical description and compilation of literature and data sources as well as ideas helping to approach the topic of energy savings on the level of the single household concerning transportation.

Keywords: Energy-saving measures, energy use, private household, household survey
1 Introduction

Decisions made in private households are a major determinant of the energy use in metropolitan regions. This can be seen in the final energy use within the City of Stuttgart, the heart of a metropolitan region with 2.7 million people in Southern Germany (VRS, n.d.). The sectors “industry” and “households” consume roughly one third each, 20 % are allotted to “transport” and 15 % to “commerce, trade and services” (Erhorn et al., 2014). The sector “households” covers mainly residential heating and electricity. But the direct and indirect influence of private households on the other sectors cannot be ignored. The most direct relation can be found in the sector “transport”. In 1999 roughly 57 % of energy consumption for transport in Germany was caused directly by private households’ car use, further 12 % indirectly by the use of mobility services as flights or public transport (Statistisches Bundesamt, 2003). The remaining energy consumption (for the sectors “industry”, “commerce, trade and services” and commercial traffic) is driven indirectly by consumption behaviour.

Due to these aspects the energy use of private households is one central topic of the project “Stadt mit Energie-Effizienz Stuttgart SEE” (City with Energy Efficiency), funded by the German Federal Ministry of Education and Research. Within the projects’ framework measures for private households lowering the direct energy consumption are examined. Both findings on the theoretical potential of energy-saving measures and on their acceptance under different boundary conditions (e.g. higher energy prices) are studied. The paper focuses on energy-saving measures in the field of transport, the computing of their potential and finally the choice of an appropriate set of measures for a particular household.

2 Aim and stages of the study – an overview

The study has a sample size of about 700 households and covers the three areas domestic heating, electricity and transport. 250 of the households are participating voluntarily, the rest is randomly chosen from the registry of the municipal registration office. A household has to meet several conditions for participating, which are checked in a short screening questionnaire.

In a next step the household data is collected. As the comprehensive survey has an average duration of two hours, two interview methods are combined. As soon as an appointment for an on-site personal interview is arranged, the online questionnaire is activated, which can be filled out by the household in a first step (Computer-Aided-Web-Interview CAWI). The
questionnaire can be completed during the appointment in a computer assisted face-to-face interview (Computer-Aided-Personal-Interview CAPI). The collected data will be presented in chapter 4.2 in more detail.

The survey data is processed automatically in the next steps. The current energy consumption of the as-is state as well as a customized set of energy-saving measures are computed. An individually designed folder is printed out for each household for presenting the results. Every suggested energy-saving measure, its energy-saving potential and its financial impact are explained individually (Figure 1).

In a second on-site appointment the folder with the suggested energy-saving measures is presented to the household. Afterwards the measures are evaluated and ranked by the household under two hypothetical situations (stated preference method). A web-based, individually adapted questionnaire is applied allowing a live-update of the displayed values and graphics (Figure 2).
The household data (as-is state) and the information on behaviour under certain conditions will be used for calibrating a microscopic household model. The model should allow forecasting trends (e.g. changes in vehicle fleet) and the reaction of households on external effects (e.g. changes in energy prices).

The aim and the stages of the study require that the measures fulfil several conditions:

- The impacts of the measures on energy consumption and financial expenses must be quantifiable and assessable.
- The implementation of measures must be in the responsibility of the households.
- The impacts of the measures must be transparent and easy to understand (adequate level of abstraction).

Figure 2: Web-based stated preference questionnaire (Source: Stadt Stuttgart, n.d.)
3 Foundations

3.1 Analysis of energy-saving potential

The energy-saving measures refer to changes on the level of single trips or aggregated groups of trips recorded in the household survey. The analysis compares the as-is state of energy consumption with a state of changed parameters. For the estimation of the energy consumption in transport the following input data is required (cf. IFEU, 2011a):

- Distance travelled
- Energy consumption of the used vehicle per kilometre
- Occupancy rate of the vehicle

The distance travelled is directly deduced from the data recorded in the household survey. Energy consumption and occupancy rate of different means of transport come from other sources. Based on average values, the two determinants are often combined in one value for energy consumption per person kilometre. Figure 3 illustrates the average energy use (all values are transferred to gasoline consumption) of the most important means of transport. The figure only shows a rough classification. As far as possible, the analysis uses values adapted to the specific situation of the individual household and measure. The following paragraphs summarize the sources for the energy consumption of different means of transport and the most important assumed simplifications.

![Figure 3: Average well-to-wheel energy consumption of different means of transport (Source: Author’s illustration)](image)

Private households use their own vehicle for most car trips (Infas, DLR, 2010). Therefore, the energy consumption per kilometre is determined for each vehicle individually (see chapter 4.2). A fleet average (as shown in Figure 3) will be assumed just if no further information is available. Also the occupancy rate is derived from the household data. The values in
Figure 3 are based on an occupancy rate of 1.3 for inner-city trips and 1.6 for long distance trips and are based on DWI, 2009 and own calculations.

Concerning public transport (PuT), figures on energy consumption are available from different studies or directly from transport companies. The study uses the sources IFEU, 2011a, DB, 2012, IFOK, Wuppertal Institut, 2012 and SSB, 2013.

That cycling is not connected to any energy consumption (Figure 3) results from the simplification that embodied energy (energy for the production of vehicles, maintenance of infrastructure etc.) and energy of muscle activity are not taken into account.

Energy consumption for flights depends highly on the flight distance as the most energy is needed for the start and landing manoeuvre. The maximum energy consumption for flights shown in Figure 3 is 8.7 litre gasoline per 100 person kilometres assuming a flight distance of 350 km. A model for estimating of the energy consumption of a flight depending on the distance travelled was developed based on data of DLR, 2008, Deutsche Lufthansa AG, 2012, IFEU, 2011b and Statistisches Bundesamt, 2012.

3.2 Possible energy-saving measures

This chapter presents a list of important energy-saving measures for private households. On a high level of abstraction measures can be classified in four types (cf. Khisty and Lall, 1998):

1. Shifting traffic from modes with high energy consumption per seat kilometre to modes with low energy consumption per seat kilometre
2. Reducing the energy consumption per seat kilometre of a mode
3. Increasing the occupancy rate
4. Reducing the distance travelled

Webpages, brochures and books, which address the target group of private households themselves, propose mostly less abstract energy-saving measures. There is a huge number of such guidebooks available, some of them also cover the subject of transport (e.g. Goerke, 2009, Stiftung Warentest (ed.), 2009, LfU Bayern, 2010 or co2online gGmbH, n.d.). Others limit themselves to the household in terms of housing space and neglect consequently the importance of transport in terms of energy consumption. The scientific literature considers energy-saving measures mainly from the perspective of decision makers (e.g. Becker et al., 2009 or Khisty and Lall, 1998). Nevertheless, it is possible to deduce energy-saving measures for private households from this literature.
The most important energy-saving measures are summarized and classified in Table 1. The classification is made according to the decisions of a household on the one hand and to the type of trip on the other hand. The most important decisions are adopted from Friedrich, 2011. The differentiation between private everyday trips, private long distance trips and business trips reflects the perception of the household members and is also relevant in terms of data collection (see chapter 4.2). For example Infas, DLR, 2010 also uses this differentiation.

Table 1: Classification of most important energy-saving measures for private households

<table>
<thead>
<tr>
<th>Trip classification</th>
<th>Type of decision</th>
<th>Private everyday trips</th>
<th>Private long distance trips</th>
<th>Business trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location choice</td>
<td>No car ownership</td>
<td>Shortening distance between living/work/further activities</td>
<td>Better accessibility by modes with low energy consumption per seat kilometre</td>
<td>Substitution of inefficient vehicle for an energy-efficient vehicle</td>
</tr>
<tr>
<td></td>
<td>Substitute for inefficient vehicle</td>
<td></td>
<td></td>
<td>Use winter tires just as long as necessary</td>
</tr>
<tr>
<td></td>
<td>Equip vehicle with low-viscosity engine oil / low rolling resistance tires</td>
<td></td>
<td></td>
<td>Remove excess weight</td>
</tr>
<tr>
<td>Activity choice</td>
<td>Homeshopping</td>
<td>Planning and combining trips (e.g. shopping just once a week)</td>
<td></td>
<td>Teleworking</td>
</tr>
<tr>
<td></td>
<td>Planning and combining trips</td>
<td></td>
<td></td>
<td>Telephone or videoconferencing instead of traveling</td>
</tr>
<tr>
<td></td>
<td>Planning and combining trips</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Choosing closer destinations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choice choice / vehicle choice</td>
<td>Use public transport instead of car</td>
<td>Use bus/train instead of car/airplane</td>
<td>Use public transport instead of car/airplane</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Walk or cycle on short trips</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use vehicle with lower energy consumption in private transport (e.g. other household owned vehicle, car sharing)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carpooling and ridesharing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Departure time choice</td>
<td></td>
<td></td>
<td></td>
<td>Avoiding traffic jams</td>
</tr>
<tr>
<td>Route choice</td>
<td></td>
<td></td>
<td></td>
<td>Avoiding detours</td>
</tr>
<tr>
<td>Driving speed choice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choice of lane</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choice of distance to car in front</td>
<td>Energy-efficient driving style (driving maximally 130 km/h on highways, turning off engine while waiting on red traffic lights, using cruise control etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Further decisions in vehicle use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As the households’ decisions in Table 1 are more or less sorted from long-term decisions (top) to short-term decisions (bottom), the energy-saving measures show a hierarchy. The first three energy-saving measures in the table (shortening distance between living/work/further activities, better accessibility by modes with low energy consumption per seat kilometre, no car ownership) lead to energy savings mainly by influencing the destination choice and mode choice. The high number of short term decisions made while driving are not considered separately but condensed under the title “energy-efficient driving style”.
4 Methodology

4.1 Pool of energy-saving measures
The selection of potential energy-saving measures for the present study and the development of the questionnaire of the household survey was an iterative process. 14 possible measures were identified which can be divided into four groups:

Investigative measures (referring to household owned vehicles)
1. Buy a fuel-efficient car (in case of purchase intension)
2. Replace a very inefficient car (in case of no purchase intension)
3. Use car sharing instead of own car
4. Use low-viscosity engine oil and equip car with low-rolling resistance tyres

Measures referring to long distance trips
5. Reduce distance of flights (recorded distance > 3,500 km) by 75 %
6. Substitute 50 % of car trips and all flights with a distance < 750 km by train
7. Fly less or shorter distances (recorded distance reduced by 50 %)
8. Substitute 50 % of car trips with a distance < 750 km by train

Measures referring to car use
9. Energy-efficient driving style and car use
10. Replace 25 % of everyday car trips (excluded are trips from or to work/education), half with public transport trips and half with cycling or walking trips
11. Use ridesharing offers (for 5 % of the distance travelled by car)

Measures referring to trips from or to work or education
12. Travel from or to work/education by public transport instead of car or motorcycle
13. Travel from or to work/education by bicycle instead of car or motorcycle
14. Travel from or to work/education by bicycle instead of public transport

Due to their various consequences and – in case of residential location choice – the complex interaction with domestic energy use (heating, electricity) the three measures mentioned first in Table 1 are not considered in the study. Also measures referring to business trips are
excluded as it is supposed that the households’ decision-making power is limited to private decisions. Furthermore, sectoral overlapping with industry and commerce energy use is avoided in this way. Company cars are excluded from the consideration due to the arguments mentioned as well.

The measure “Energy-efficient driving style and car use” implies not only all decisions while driving but also the condition of the households’ vehicles influencing the energy consumption perceptible (tyre pressure, excess weight).

4.2 Data collection

In contrast to domestic energy use, transport energy use is not documented in energy bills in most cases. Consequently the computation of the as-is state and of the savings by certain measures is based on the same input data. As shown in chapter 3.1 the information needed is basically the distance travelled on different level of aggregation and the energy consumption per vehicle kilometre. Therefore the survey contains four major parts concerning transport: vehicles of the household, long distance travels, questions on personal level to the household members and a trip diary.

The systematization of the questionnaire concerning the kilometres travelled by the household is shown in Figure 4. Trips are classified in private motorized transport, public transport and non-motorized transport. Even if non-motorized transport is neglected in terms of energy use, data is sampled to reach a clearer understanding of the households’ travel behaviour. The differentiation between everyday trips and long distance trips is defined by a straight line distance of 100 km.
Every member of the household older than 9 years is asked to fill out a trip diary for one week. It follows the approach used in Infas, DLR, 2010. Extrapolating the trip diary data of one week for the calculation of the annual kilometres travelled on household level carries a substantial risk of a statistical error. Therefore, as far as possible at least one other method of data collection is used for each class of trips (except for non-motorized transport).

The distance travelled from or to work or education (from now on just called “work trips”) is calculated for each household member reporting a permanent workplace. The geographic coordinates of the workplace are recorded in a map and used to calculate the distance between work and home. The frequency of work trips per week is deduced from the occupation of the person. The household survey also covers the main mode of transport for work trips.

Long distance trips occur very infrequent compared to everyday trips but are highly relevant for the energy consumption (roughly 22 trips > 100 km per year cause about 45 % of the distance travelled per person in German average (Frick and Grimm, 2014)). For that reason, long distance trips are recorded in the survey retrospectively for one year. For each long
distance trip (journey there and back aggregated for the household) several items are recorded. Trips with similar characteristics can be aggregated stating the frequency. Recorded are: the destination (implemented by a drop-down list of countries and the respectively filtered regions), main means of transport, trip purpose, number of nights, number of attending household members and frequency of the journey. For all calculations is assumed that the journeys start from Stuttgart. For a round trip just the destination located furthest away is asked.

Concerning the households’ vehicles the household is asked to estimate the vehicle kilometres travelled per year for private trips and business trips. The reliability of such data is investigated in RWI, forsa, 2013. The household survey also covers an estimation of each person for the distance travelled by public transport per week.

Besides the vehicle kilometres travelled the questionnaire contains items to determine the energy consumption per kilometre of each vehicle. As shown in Figure 5 the filtering of the questionnaire allows several approaches.

![Diagram](image)

**Figure 5:** Filtering of vehicle questionnaire (Source: author’s illustration)

By entering the German manufacturer key number and the type key number for cars and mobile homes the vehicle can be matched to one unique entry in the vehicle-database (ADAC, 2013) providing all required information for further calculations (as the data on fuel consumption of the database is based on manufacturers data, the values are increased by 10 % - a conservative estimation according to Mock et al., 2013). If manufacturer key number
and type key number are either not available or not found in the database, the questionnaire will permit entering the fuel consumption directly. The last option is estimating the vehicles' energy consumption based on fleet consumption values of the German Handbook of Emission Factors (Infra, 2010) using the items construction year, displacement and energy source.

The following further items are recorded on vehicle level:

- Use of low-viscosity engine oil
- Equipped with low-rolling resistance tyres
- Plan of replacing the vehicle
- Regular control of tyre pressure
- Transport of excess weight

Additionally, the following information about the household members is used to select suitable transport energy-saving measures:

- Type of public transport ticket and weekly costs
- Possession of a BahnCard
- Possession of car driving licence and car availability
- Bike availability
- Use of car sharing
- Use of ridesharing
- Favourite speed on motorway
- Driving style
4.3 Preconditions and potential of energy-saving measures

4.3.1 Investigative measures

All technical measures refer to one certain vehicle of the household. For each vehicle only one measure can be chosen. Table 2 sums up the preconditions, which have to be fulfilled for proposing one of these measures:

Table 2: List of investigative energy-saving measures with preconditions

<table>
<thead>
<tr>
<th>Energy-saving measure</th>
<th>Preconditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buy a fuel-efficient car (in case of purchase intention)</td>
<td>• Replacement planned within the next 3 years</td>
</tr>
<tr>
<td></td>
<td>• More than 5,000 km vehicle kilometres travelled per year</td>
</tr>
<tr>
<td></td>
<td>• Match in vehicle-database</td>
</tr>
<tr>
<td>Replace a very inefficient car (in case of no purchase intention)</td>
<td>• No replacement planned within the next 3 years</td>
</tr>
<tr>
<td></td>
<td>• More than 5,000 km vehicle kilometres travelled per year</td>
</tr>
<tr>
<td></td>
<td>• Recorded car shows a 30 % higher fuel consumption than new vehicle</td>
</tr>
<tr>
<td></td>
<td>• Match in vehicle-database</td>
</tr>
<tr>
<td>Use car sharing of instead own car</td>
<td>• Less than 5,000 km vehicle kilometres travelled per year</td>
</tr>
<tr>
<td></td>
<td>• More cars owned than household members going to work/education by car</td>
</tr>
<tr>
<td></td>
<td>• Household is not using car sharing frequently already</td>
</tr>
<tr>
<td></td>
<td>• Match in vehicle-database</td>
</tr>
<tr>
<td>Use low-viscosity engine oil and equip car with low-rolling-resistance tyres</td>
<td>• One of both products is not used or household does not know about it for both products</td>
</tr>
<tr>
<td></td>
<td>• More than 5,000 km vehicle kilometres travelled per year</td>
</tr>
</tbody>
</table>

The energy-saving potential is caused only by differences in fuel consumption per vehicle kilometre. The vehicle kilometres travelled are assumed not to change by applying one of these measures. The fuel consumption of a new energy-efficient car in the first two measures is deduced from the vehicle-database (ADAC, 2013). The 25 %-quantile of the values in each vehicle category is used reflecting the energy-efficiency of the new model.

The potential of low-viscosity engine oil or low-rolling resistance tyres is described by constant reduction factors:

- The fuel-saving potential of using low-viscosity engine oil instead of conventional engine oil depends on the specific engine, temperature of the engine, traffic flow, driving style and further factors. These external determinants are roughly represented in the differentiation between inner-city traffic and inter-city traffic. Based on Taylor and Coy, 2000 and Bartz, 2000 the very conservative assumption of 3 % energy savings for inner-city trips and 1 % for inter-city trips was made.
For the use of low-rolling resistance tyres 2 % energy savings for inner-city trips and 4 % for inter-city trips are assumed. The author is not aware of robust scientific studies on this field. Values can be found in Vennebörger et al., 2013, Schedel, 2002 and Smokers et al., 2006.

4.3.2 Measures referring to long distance trips

Regarding long distance trips the possible energy-saving measures are limited to changes in destination and mode choice.

Table 3: List of energy-saving measures referring to long distance trips with preconditions

<table>
<thead>
<tr>
<th>Energy-saving measure</th>
<th>Preconditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce distance of flights (recorded distance &gt; 3,500 km)</td>
<td>• At least one flight to a destination further away than 3,500 km was recorded</td>
</tr>
<tr>
<td>Substitute 50 % of car trips and all flights with a distance &lt; 750 km by train</td>
<td>• At least one flight with a destination closer than 750 km was recorded</td>
</tr>
<tr>
<td>Fly less or shorter distances (recorded distance reduced by 50 %)</td>
<td>• Number of flights recorded &gt; number of household members or sum of flight distance &gt; number of household members multiplied by 2,000 km</td>
</tr>
<tr>
<td>Substitute 50 % of car trips with a distance &lt; 750 km by train</td>
<td>• At least 6 car trips with a destination closer than 750 km where recorded</td>
</tr>
</tbody>
</table>

These measures overlap concerning their potential. Therefore the following combinations are excluded: First and third measure of Table 3, second and third measure, second and forth measure.

The distance of each journey is computed based on the geographic coordinates of the origin (Stuttgart) and the destination. It is generally assumed a detour factor of 1.3 (except for flights). As the energy consumption per person kilometre of trips per airplane depends on the flight distance, the energy-saving potential is calculated per trip for the first two measures of Table 3. The third measure does not allow this approach. In this case the simplification of reducing the sum of energy consumption of all flights by 50 % is employed.

4.3.3 Measures referring to car use

Two of the three measures referring to car use (Table 4) aim for the whole households’ vehicle kilometres travelled (driving style, use ridesharing), the other one only at the everyday trips (reducing car use for everyday trips):
Table 4: List of energy-saving measures referring to car use

<table>
<thead>
<tr>
<th>Energy-saving measure</th>
<th>Preconditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy-efficient driving style and car use</td>
<td>• Fuel-saving potential &gt; 2 % of energy consumption in private transport</td>
</tr>
<tr>
<td>Replace 25 % of everyday car trips (excluded are trips from or to work/education), half with public transport trips and half with cycling or walking trips</td>
<td>• Modal share of private transport (trip based consideration) in everyday trips (work trips excluded) is higher than the 0.33 (average of Stuttgart inhabitants)</td>
</tr>
<tr>
<td>Use ridesharing offers (for 5 % of the distance travelled by car)</td>
<td>• No member of the household uses ridesharing so far</td>
</tr>
<tr>
<td></td>
<td>• Vehicle kilometres travelled per year &gt; 10,000 kilometre per year</td>
</tr>
</tbody>
</table>

The energy-saving potential of an economic car use implies in the adapted model four behavioural factors. The calculation employs one item of the household survey per factor, either on personal or household level:

- **Driving style (personal level):** As already shown in Table 1 the driving style includes a multitude of energy-relevant decisions. In the work of Berry, 2010 these decisions are condensed in a so called aggressiveness factor that shows a clear correlation to fuel consumption. It was found, that a “normal driver” can reduce fuel consumption by roughly 5 %. Many other studies examine the topic by evaluating the effects of drivers training. Barkenbus, 2009 employs a conservatively calculated average fuel-saving potential of 5 % which can be reached by training without feedback. Based upon that, 10 % energy-saving potential is assumed for household members claiming “I prefer driving fast and sporty” und 2 % for claiming “I know some energy saving methods and try to follow them”.

- **Preferred speed on motorways (personal level):** It is assumed, household member who like to drive faster than 130 km/h on motorways are able to save energy by reducing the speed. The relation between driving speed and fuel-consumption was examined e. g. by FU Berlin, n.d. (see Figure 6) or Berry, 2010. The mathematical relation found in both studies is similar.
Using the information that roughly 65% of the German motorways have no speed limit (BAST, 2010) and assuming conservatively that only 50% of the inter-urban kilometres travelled are done on motorways and that the traffic situation allows driving the desired speed only in 50% of all cases still leads to a high energy-saving potential: Household members stated a desired speed of 140–159 km/h / 160-179 km/h / >= 180 km/h can reduce their fuel consumption by 5.5% / 12.5% / 20% in case of diving 130 km/h in maximum.

- **Tyre pressure (household level):** A low tyre pressure can increase the fuel consumption per kilometre considerably. UBA (ed.), 2009 reckons an increase of 5% for a reduction of the tyre pressure by 0.5 bar. Gruden, 2008 indicates 2 to 3% additionally fuel consumption for a tyre pressure 20% below the manufacturer instruction. Based upon that a possible energy-saving potential of 3% will be chosen, if a household replies to the item “Do you check the tyre pressure regularly and is it at least on the level of manufacturer instruction?” with “No”.

- **Excess weight (household level):** Raising the energy-efficiency of vehicles by lowering the weight is a typical subject of vehicle design. The assumed reduction potential of 1.5% is a rough estimation for 20 - 80 kg excess weight which can be avoided. As sources can be mentioned e. g. Gruden, 2008 (0.3-0.8 l/100km savings per 100 kg mass reduction) and Smokers et al., 2006 (0.9 – 1.0 % reduction of CO₂ emissions for a weight reduction between 15 and 54 kg)
4.3.4 Measures referring to trips from or to work or education

Finally, three measures focus on mode choice for work trips (Table 5):

Table 5: Energy-saving measures concerning work trips

<table>
<thead>
<tr>
<th>Energy-saving measure</th>
<th>Preconditions</th>
</tr>
</thead>
</table>
| Travel from or to work/education by public transport instead of car or motorcycle | • Place of work or education is in the area of the transport association of Stuttgart (spatial attribution to transport model zone possible)  
• Main mode of transport is car or motorcycle  
• 1.5 * Travel time by car > Travel time by public transport  
• Travel time by car + 30 min > Travel time by public transport |
| Travel from or to work/education by bike instead of car or motorcycle | • Place of work or education is in the area of the transport association of Stuttgart (spatial attribution to transport model zone possible)  
• Main mode of transport is car or motorcycle  
• Travel time by bicycle <= 30 min  
• Bicycle availability |
| Travel from or to work/education by bike instead of public transport | • Place of work or education is in the area of the transport association of Stuttgart (spatial attribution to transport model zone possible)  
• Main mode of transport is public transport  
• Travel time by bicycle 30 min in maximum  
• Bicycle availability  
• Already low transport energy consumption: No long distance trips per airplane and no work trips by car. |

These measures are on personal level. For each person of the household only one of the measures can be chosen. The calculations are based on characteristic values for the relation between home and work (travel time, travel distance, costs). They are read-out of the skim matrices of the travel demand model of the region of Stuttgart. For that reason, the geographical coordinates of the place of residence and the place of work or education of every household member are attached to one transport model zone.

Travel times for private motorized transport contain apart from the running time also time for searching a parking space which is specific for each destination zone. The driving speed of bicycle travels is 15 km/h in average and is reduced or increased on sloped links. The travel time calculation for public transport contains the principal issue of relatively big model zones in the suburban areas around Stuttgart. Even if the attached zone has a good connection to the public transport system, the actual place of work or education can show a low accessibility.
4.4 Generating a set of energy-saving measures

After processing the computing of each measure (checking the preconditions, calculating the energy-saving potential) the possible measures are composed to a measure set. According to a workshop of experts in energy consultancy, not more than 12 measures should be presented to a household (four each referring to electricity, heating and transport). Further was recommended to split the measures in two groups: investigative and behavioural orientated measures (cf. Wassermann et al., 2013). Consequently two investigative and two behavioural orientated transport measures can be selected in the study.

The measures are selected by maximizing the sum of energy savings. Firstly the exclusion of measures aiming at the same potential (see chapter 4.3) is accomplished.

Nevertheless, the energy-saving potential of the remaining measures cannot be considered as independent (e.g. driving less kilometres with a new energy-efficient car). This fact should be pointed out to the households and considered in the selection of measures. Therefore the investigative measures with the highest energy-saving potential are chosen. Afterwards the behavioural orientated measures are calculated again for a hypothetical situation with new technical equipment. The process is repeated for behavioural orientated measures influencing each other’s potential (e.g. driving less and change in driving style).

5 Outlook

The procedure of data collection (household survey, energy consultation and stated-preference experiments) will be completed in autumn 2014. A clear understanding of the selection of measures for a household is necessary for the analysis of the results.

The results of the study should help to understand households’ decisions and evaluate the impact of political measures. So far, studies on this topic are often limited either to transport or residential energy use. Involving the whole spectrum of direct energy use of private households in the consideration is one advantage of the present project. Confronting households with specifically arranged energy-saving measures allows the promising prospect of reviewing the existing results of studies addressing both areas of energy use (e.g. Poortinga et al., 2003) and new findings on households’ preferences and their possible contribution reaching the objective of saving energy.
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